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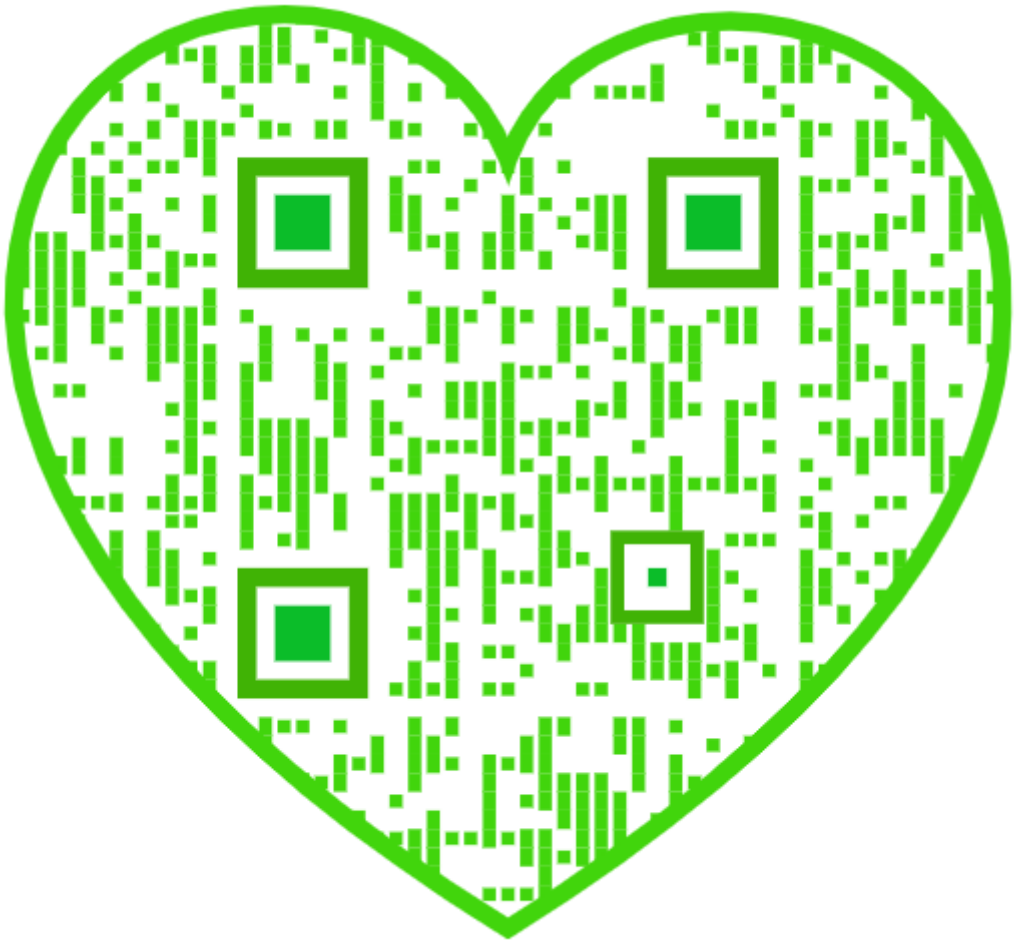
A COURSE IN MECHANICAL DRAWING

LOUIS ROUILLION



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A COURSE IN
MECHANICAL DRAWING

FOR SCHOOL USE AND FOR SELF-INSTRUCTION

A PRACTICAL TREATISE ON THE ART OF MAKING WORKING DRAWINGS, LETTERING AND DIMENSIONING

BY

LOUIS ROUILLION, B.S., A.M.

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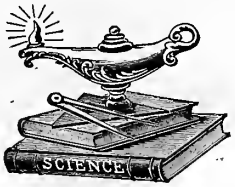

FIFTEENTH EDITION, REVISED AND ENLARGED

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No 1

PREFACE

THIS course in Mechanical Drawing is the result of a number of years' work with evening classes, and has been evolved from a careful study of the needs of such classes. The course was originally issued in blue-print form, with accompanying typewritten notes. In this form it has been in use at Pratt Institute and other schools, and in Y. M. C. A. classes, for some years. In a modified form it has appeared serially in "Machinery."

The course covers a period of two school years of about twenty-four weeks each. Either two or three evenings a week may be devoted to the work. In the former case it may be found necessary to abridge the number of simple working drawings. The first twenty-four sheets constitute the work of the first year, and sheets XXV–XXIX that of the second year.

Because of the interest in Isometric Drawing evinced by pupils, this subject has been added to the present edition. Isometric Drawings—Sheets XXX–XXXII may advantageously follow Sheet XIII in the first-year course.

The exercises given at the end of the book, form a parallel independent course permitting the use of the book as a text-book in class work.

All drawings shown in this book are the work of students.

November, 1921

LOUIS ROUILLION.

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COURSE IN MECHANICAL DRAWING.

GENERAL INSTRUCTIONS.

REQUIRED MATERIALS.

In order that acceptable work may be accomplished, fairly good instruments should be provided. The cheap brass sets that are sometimes offered by dealers for use in schools are worse than useless. The advice of some one experienced in draughting instruments should be sought before purchasing. The following list of materials required for this course gives approximate prices that may be considered as inexpensive as it is advisable to obtain.

LIST OF MATERIALS.

Drawing board, about 16 x 23 inches	$1.00
Compasses, $5\frac{1}{2}$ inches, with needle point, pen, pencil and lengthening bar	2.00
Drawing pen, $4\frac{1}{2}$ inches	.70
T-square, 24-inch blade	.45
45° triangle, 9 inches	.45
30°–60° triangle, 11 inches	.40
Celluloid scroll	.50
Pencil	$ .05
12-inch boxwood scale, flat, graduated to $\frac{1}{16}$ inch the entire length	.40
Bottle of liquid India ink	.25
Tacks	.05
Pencil and ink eraser	.05
	$6.30

Drawing paper.

USE OF MATERIALS.

DRAWING BOARD. A light board having a smooth surface and the left-hand edge trued perfectly straight will serve as a drawing board. It should be somewhat larger than the largest sheet of paper that is to be used upon it. The left-hand edge serves as a guide for the head of the T-square. The left and right-hand edges should be composed of narrow strips, the grain of which runs across that of the board.

PAPER. The drawing paper should have a surface that will permit of considerable erasing without becoming roughened. When working by artificial light it is desirable that the paper be of a light-brown color which is less trying to the eyes than a pure white. Paper may be purchased in sheets 22 x 30 inches, that make four exercise sheets, each measuring 11 x 15 inches.

The sheet is tacked upon the board as shown in the Diagram opposite (Fig. 1), being placed well over towards the left-hand side of the board, thus permitting greater firmness in the use of T-square and triangles.

Thumb tacks may be used for securing the paper to the board, or one-ounce tacks, which should be driven well into the board. These latter have the advantage of offering less obstruction to the use of the T-square. When large sheets are used and the drawing requires considerable time, the paper may be stretched upon the board.

The paper is stretched by turning up about an inch of the paper all around the edge and thoroughly wetting the trough thus formed. The edge is turned up to keep it dry, so that it may be used for glueing. See that the edge is firmly glued to the board. When the paper is dry it will be found to be smoothly stretched. When the drawing is completed, the sheet may be cut out with a sharp knife. The T-square or triangle should not be used as straight-edges for trimming sheets.

DRAWING-BOARD, T-SQUARE AND TRIANGLES.

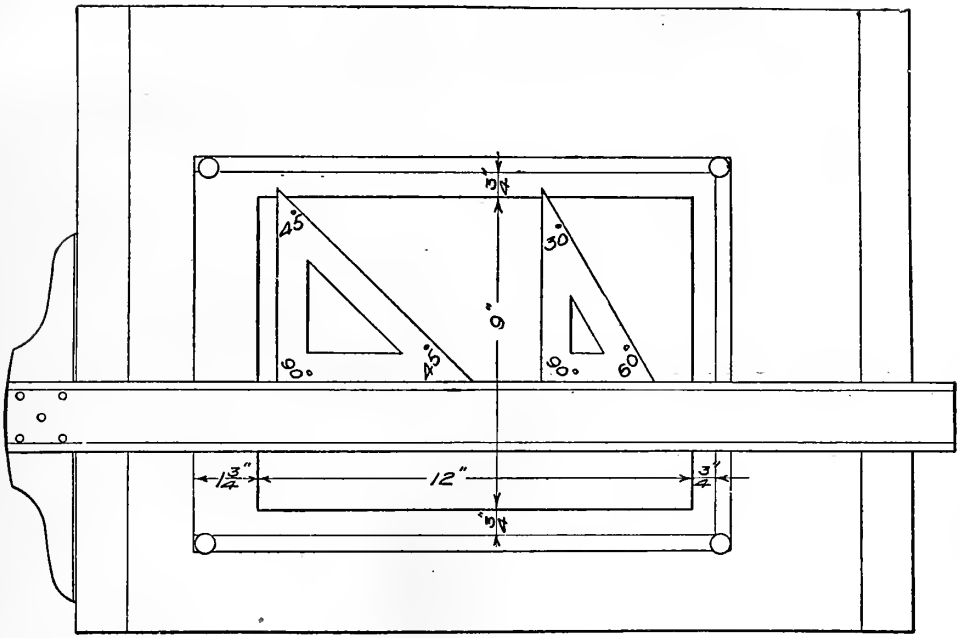


FIG. 1.

T-SQUARE. The head of the T-square is always kept against the left-hand edge of the board and its upper edge is used in drawing all horizontal lines and for resting the triangles upon.

TRIANGLES. The triangles are used in drawing all straight lines other than horizontal ones. They are rested upon the upper edge of the T-square, and thus afford means of drawing vertical lines and lines at 30°, 45° and 60°. By placing one triangle upon the other, angles of 15° and 75° may be obtained. A perpendicular may be drawn to any line situated at an angle other than those mentioned, by placing either triangle upon the other so that its hypotenuse coincides with the line, and then revolving it through an angle of 90°.

COMPASSES. The compasses are supplied with needle-points, pen and pencil, and are used for drawing circles and arcs of circles. By placing needle-points in each of the legs, the compasses may be used as dividers in stepping off distances. Supposing it is required to divide a given line into seven equal parts. The compasses are opened to an approximation to one of the parts and seven of these parts are stepped off lightly, without puncturing the paper. The error is noted and the compasses reset to a closer approximation, and the process continued until the required division is obtained. The paper is then lightly punctured at each step. The line may be either straight or curved. Determining a point by a needle prick has the advantage over a pencil-point in that it is not lost by erasure, and is more accurately determined. The position of the point is emphasized by drawing a small circle in pencil about it.

For penciling circles or arcs of circles, the pencil is placed in one leg of the compasses and the needle-point in the other. The legs should be bent at the joints until the lower extremities are parallel, or nearly so. The

compasses are held at the joint, rotated clockwise, and inclined slightly in the direction of the line. A slight pressure is exerted. In inking, the pen is substituted for the pencil, and the weight of the compasses is sufficient to cause the ink to flow.

Drawing Pen. The pen is filled by dropping the ink between the nibs while held in a nearly vertical position.

In inking, the pen is held between the thumb and forefinger. Care should be taken that the nibs are not pressed together while the pen is thus held, as a line of varying thickness would result.

The flat side of the point is laid against the edge of the T-square or triangle and the pen held within the plane of that edge. The taper to the point is sufficient to throw it far enough from the edge to prevent blotting. The handle should be tilted about 35° to the right of perpendicular. Draw from left to right and from the bottom to the top. The breadth of a line may be controlled by the adjusting screw.

If the pen is not in use, even for a short time, the ink should be taken out, as it evaporates quickly and clogs the pen. For this purpose, pass the corner of a piece of chamois skin between the nibs of the pen. Keep the nibs of the pen at all times bright and clean.

Pencils. A soft pencil, sharpened to a round point, should be provided for putting in letters, figures, arrow-heads and other free-hand work, and for making sketches. A hard pencil, sharpened to a flat chisel-like edge, should be used for drawing all lines with the aid of the instruments. The pencil should be used lightly, so as not to indent the paper. A small flat file, or a piece of fine sand-paper should be at hand, over which the pencil may be occasionally rubbed. For erasing pencil marks, a soft rubber should be provided, and a hard or sand rubber for erasing ink.

SCROLL. The scroll is used in obtaining curves other than arcs of circles. If a curve is to be passed through a number of predetermined points, it should first be sketched in lightly free-hand. A section of the scroll is then applied to the curve so as to embrace as many points as possible. Only the central points of those thus embraced should be inked in. This process is continued until the desired curve is completed.

SCALE. When practicable, objects should be drawn full size. When an object is too large to permit of this, it may be drawn to the largest convenient scale. With the measuring scale recommended for this course drawings may be made to half or quarter scale. By half-scale is meant that each half-inch upon the drawing represents a full inch upon the object. A special scale may be made as follows: Supposing it is desired to make a drawing to five-eighths scale; that is, that each inch upon the object will be represented by five-eighths of an inch upon the drawing. Take a slip of paper and measure off upon its edge five-eighths of a foot. Divide this distance into twelve equal parts, and each of these divisions into halves, quarters and eighths. In using such a scale treat it as though it were a full scale; *e. g.*, if the object being drawn measures $11\frac{1}{2}$ inches, read $11\frac{1}{2}$ inches from the reduced scale, make the drawing accordingly, and dimension as $11\frac{1}{2}$ inches.

INK. The liquid India ink that comes in bottles is generally used for school work, and answers all requirements. Some draughtsmen prefer the stick ink, which gives somewhat better results, but requires preparation. Black ink alone should be used, except on tracings where lines that may be printed lightly, as dimension and construction lines, may be in red ink. Do not place too much ink between the nibs of the pen. A column of from one-quarter to three-eighths of an inch high is all that should be used at a time.

LETTERING.

It is desirable to confine the lettering of drawings to one or two standard alphabets that are plain and distinct, and the principles of which are easily acquired. These conditions are fulfilled in the Gothic fonts shown in Fig. 2. To analyze each letter and study its correct proportions and relations to other letters under varying combinations, would consume more time than can be alloted in this course. Therefore, a simple expedient may be resorted to, by which all the capitals, with the exception of I, J, M, and W, may be considered as having the same breadth. This breadth should be about five-sixths of the height. The inclination of the slant letters is about 20 degrees to the right of perpendicular. The upper parts of letters are made slightly smaller than the lower parts. The basis of the curved lower-case letters of the vertical font is a circle. Other characteristics may be noted by a careful inspection of the examples given.

All lettering should be free-hand. Keep the pencil sharpened to a fine, round point. If the lettering is to be done in ink, a common writing-pen may be employed, or the drawing pen may be used as an ordinary pen.

The titles for the sheets given on the following pages are composed of $\frac{3}{16}$-inch letters. The O of the lower-case has a diameter of $\frac{1}{8}$ inch.

In putting the title upon a sheet, first draw two lines $\frac{3}{16}$ inches apart along the edge of a slip of paper and sketch in the title, to ascertain the amount of room it will occupy. Then draw lightly upon the sheet, $\frac{3}{4}$ inches below the top marginal line, two horizontal lines $\frac{3}{16}$ inches apart, and the central vertical line of the sheet. Fold the slip of paper so that the end letters of the title will coincide.

The fold will then be the centre point of the title. Lay the slip directly below the lines drawn on the sheet, so that the centre point of the sketched title will coincide with the centre line of the sheet. The location of

the title is thus quickly determined and may now be carefully drawn, using the sketch as a guide.

The dimension-figures should be a scant eighth-inch in height. The division line of fractions should be parallel to the direction of the dimension line.

MODELS.

Geometric models are chosen as the subjects for the earlier exercises, as they are so simple in form. Moreover as types of all forms, they present the underlying forms in mechanical construction, however complex that construction may be. They serve, then, not only as simple models for elementary practice, but also as giving the form basis for the most advanced work. The geometric models presented are—cube, equilateral triangular prism, hexagonal prism, square pyramid, cone, hollow cylinder, truncated hexagonal prism, and cross. It will be well for students to study the models and objects in making the drawings.

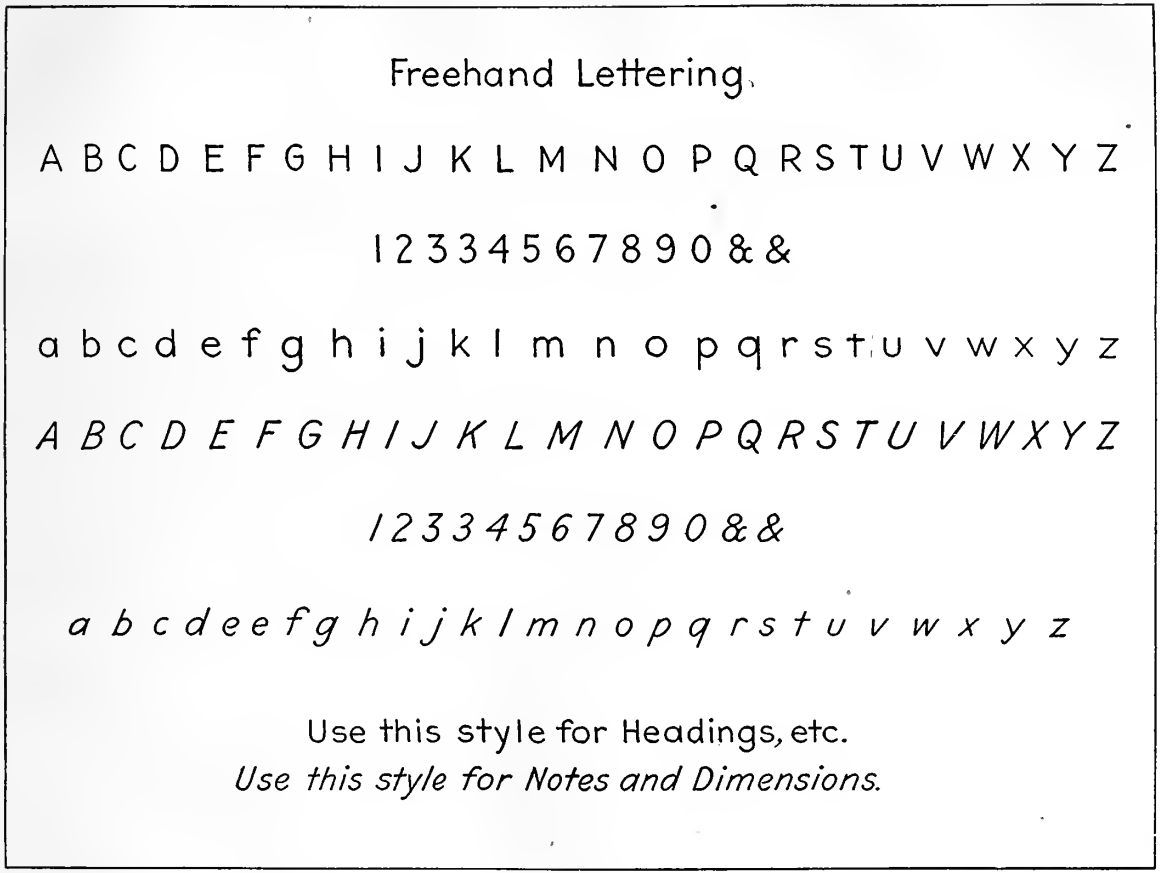
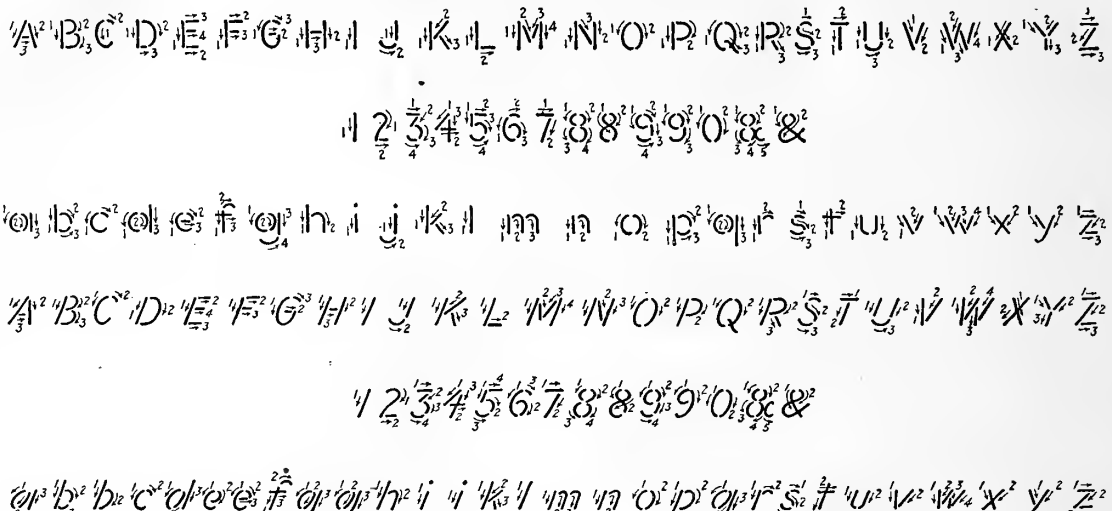

Freehand Lettering.
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
1 2 3 3 4 5 6 7 8 9 0 & &
a b c d e f g h i j k l m n o p q r s t u v w x y z
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
1 2 3 3 4 5 6 7 8 9 0 & &
a b c d e e f g h i j k l m n o p q r s t u v w x y z
Use this style for Headings, etc.
Use this style for Notes and Dimensions.

FIG. 2

Construction of Freehand Lettering.



Note: Arrows indicate direction of pen strokes.
Numbers show the order in which strokes are to be made.

REGULAR COURSE

REGULAR COURSE EXERCISES.

SHEET I.

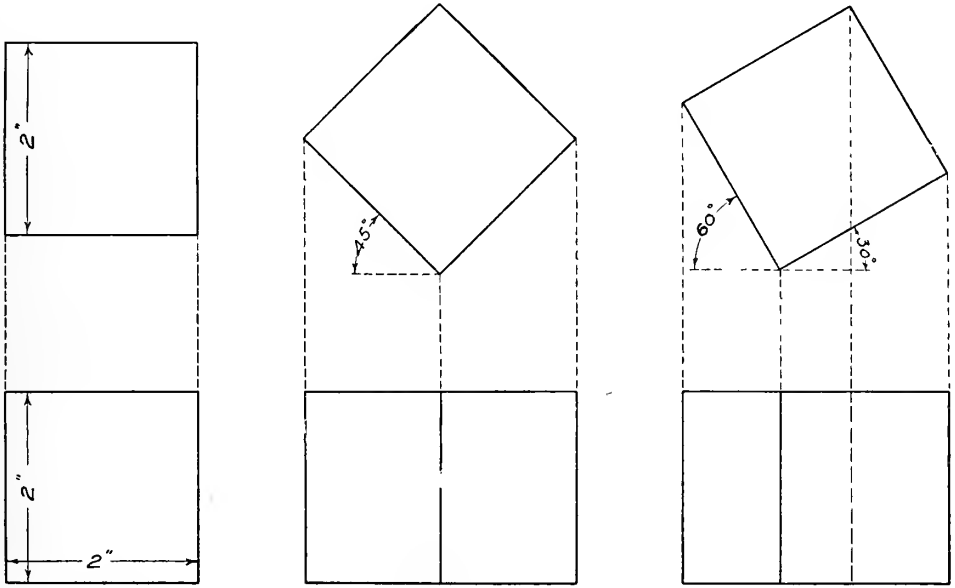
Cubes — Top and Front Views.

This sheet gives the top and front views of a cube in three positions — facing, turned at 45°, turned at 60° and 30°. At the left of the sheet the top and front views of the cube facing are shown. Draw a 2-inch square as shown in the upper left-hand corner, using the upper edge of the T-square for the top and bottom lines and a triangle resting upon the T-square for the sides. This is the top view of the cube facing. Continue the vertical lines below the lower horizontal line, the top view thus obtaining the side lines of the front view, and draw the top and bottom lines two inches apart. The two views required are now completed. After the drawing is finished the dimensions should be put on. As a cube has length, breadth and depth, three measurements should be given. The length and breadth are here shown on the front view and the depth on the top view.

In the centre of the sheet two views of the cube turned at an angle of 45° are shown. The top view must first be drawn and is obtained with the 45° triangle. From the corners lines are dropped as in the first case and the top and bottom lines are drawn, completing the front view.

At the right of the sheet, two views of the cube turned at 60° and 30° are shown. The top view is turned so as to form angles of 60° and 30° with the horizontal. The 60° and 30° triangle is used in drawing this view. The front view is obtained as in the previous cases. It will be seen that whereas in the second case the front and back edges of the cube coincide in the front view, in this case the back edge falls to the right of the front edge and is hidden. This is shown by putting in the back edge with a broken line, called a "hidden line." The lines here used in showing the relation of the top and front views are called "construction lines," made up of dashes a scant $\frac{1}{8}$ inch in length. Directions for drawing hidden lines are given on page 66.

CUBES



SHEET II.

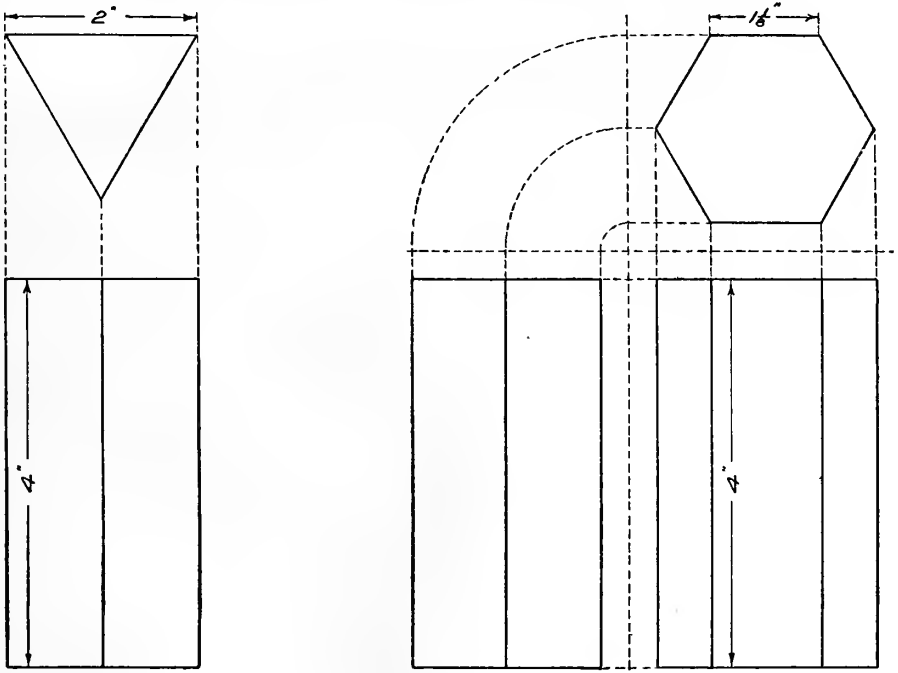
Triangular and Hexagonal Prisms.

Prisms are solids having their ends parallel, and the edges formed by their sides parallel, and are known as triangular, hexagonal, etc., from the form of their bases. Before making the drawings, consider how to place them well upon the sheet.

Two views of the equilateral triangular prism are given. First draw the equilateral triangle for the top view, using the 60° triangle for the sides, and complete the two views to the dimensions given.

In the case of the hexagonal prism, three views are shown: the top, front and left-hand views. To obtain these, first draw a hexagon with $1\frac{1}{8}$ inch sides for the top view. This is done by drawing the lower line and cutting off the desired length. Then with the 60° triangle draw the lower side lines and cut off $1\frac{1}{8}$ inches. The upper side lines are also drawn with the same triangle and the hexagon is completed by adding the top line. The front view is obtained as in the case of the triangular prism. The height in the side view is the same as in the front view, and distances from side to side are obtained directly from distances from top to bottom in the top view. This relation of the top and side views is shown in the drawing by the construction lines.

TRIANGULAR AND HEXAGONAL PRISMS



SHEET III.

Projection of Square Pyramid.

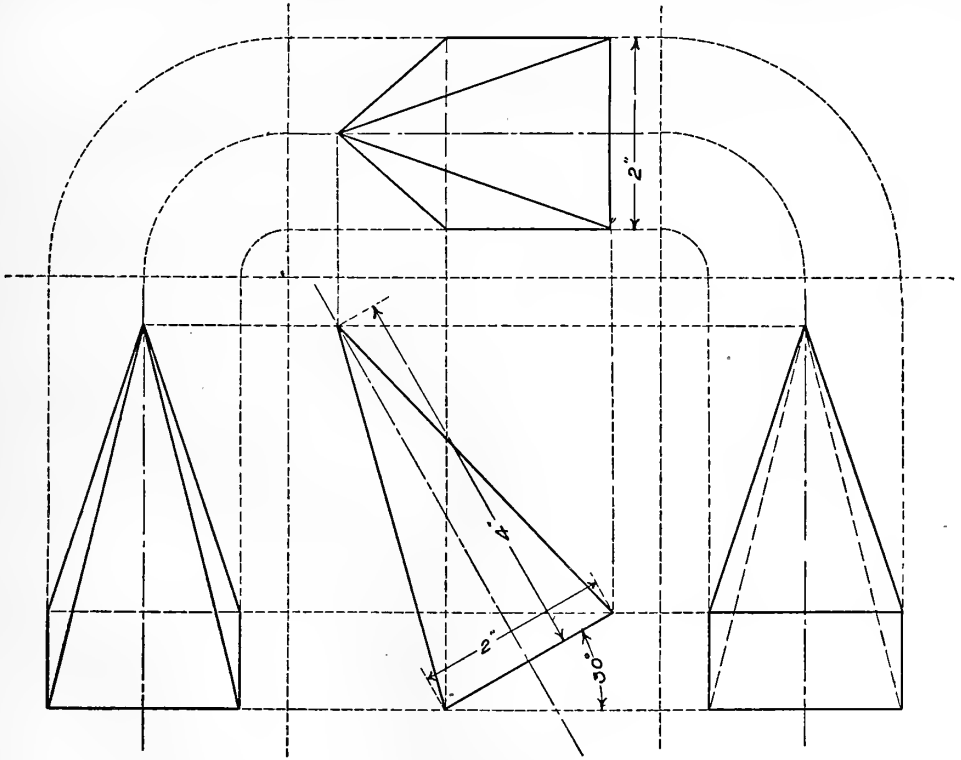
This sheet shows the relation of the various views of an object and the proper method of projecting one view from another.

First draw the base line of the pyramid in the front view at an angle of 30 degrees to the horizontal and cut off the required length of two inches. At the centre of this base line erect a perpendicular to it to serve as a centre line. This is drawn with the 60-degree triangle. Mark off on this centre line a distance of four inches from the base line. Join this point with the extremities of the base line, completing the front view. At a suitable distance, say two inches, above this view, draw a horizontal line as the centre line of the top view, and one inch on either side draw lines parallel to it. Complete the foreshortened view of the base by drawing vertical lines upward from the extremities of the base line of the front view. The apex of the pyramid is on the centre line. The point is determined by drawing a vertical line from the apex in the front view, and is where this line intersects the centre line. Complete the top view by joining the apex to the corners of the base.

To obtain the left-hand view, first draw the vertical centre line at a convenient distance to the left of the front view. This centre line corresponds with the centre line shown in the top view, therefore all distances above the centre line in the top view are equal to distances to the left of the centre line in the left-hand view, and distances below the centre line in the top view are equal to distances to the right of the centre line in the left-hand view. As in **Sheet II** these relations are shown by construction lines. For the base line, therefore, measure off one inch either side of the centre line, and erect perpendiculars for the sides of the base. Cut off the required length by projecting a horizontal line from the tilted-up corner of the base in the front view, and complete the view as in the case of the top view. The right-hand view is obtained in a similar manner.

In inking, show all edges that are actually seen, by full, strong lines. Where an edge is hidden by a face in front of it, show it by "hidden lines." Centre lines are drawn lightly, and are made up of dashes alternately one-half and one-eighth inches long

PROJECTION OF SQUARE PYRAMID



SHEET IV.

Projection of Cross.

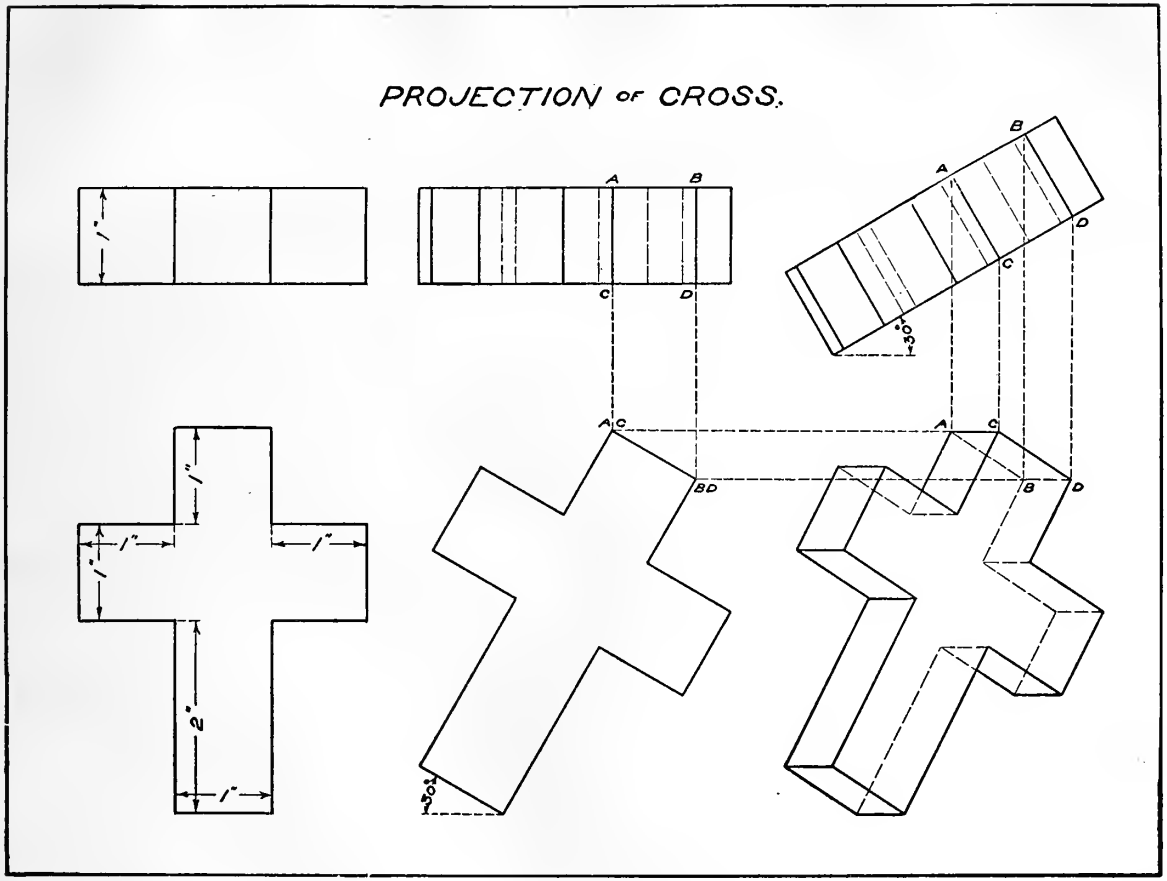
This sheet emphasizes the method of projecting one view from another, and shows how any one view may be obtained directly from two other views by this means, and also how a view is rotated so as to show three sides.

Draw the top and front views of a cross to the dimensions given as shown at the left of the sheet.

For the central group, tip the front view 30° to the right, and obtain the top view by projecting similar points from this view and the top view of the left-hand group. Care should be used in getting the hidden lines correctly.

In the left-hand group the cross is shown standing erect on its base and squarely facing the observer. In the central group it is shown still facing the observer, but tilted to the right. In the right-hand group it is desired to show the cross turned 30° away from the observer, while still tilted as before. The turning of an object about a perpendicular axis may be shown by turning the top view in the desired direction and through the desired angle.

Therefore, as we want to show the cross turned away at an angle of 30°, we rotate the top view through the required angle. The final view is obtained from this rotated top view and the front view of the central group. One face A B C D is shown projected. Similar letters refer to similar angles in the various views.


PROJECTION of CROSS.
1"
A
B
C
D
50°
1"
1"
1"
1"
2"
1"
A C
B D
A
C
B
D
50°

SHEET V.

Hollow Cylinders.

This sheet introduces the use of the compasses. In one leg of the compasses insert the needle-point, and in the other leg insert the pencil, carefully sharpened.

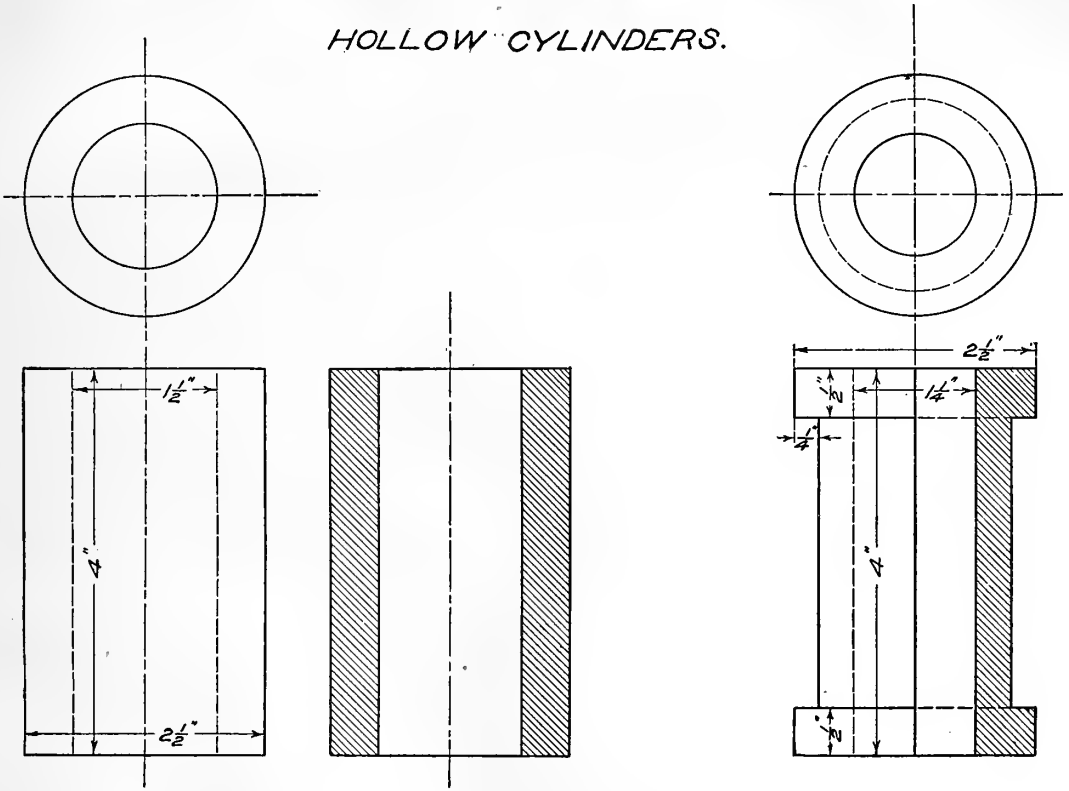
Locate the centre lines and draw the two concentric circles to represent the top view of the cylinder at the left. Then draw the front view by projecting the side lines from the top view.

The view shown immediately to the right of these two views is known as a "sectioned" view. Imagine the cylinder cut in halves from top to bottom. The back half would present the appearance shown in the sectioned view, the "cross-hatching" or "sectioning" representing the cut surface. The sectioning is done by drawing a series of parallel lines about $\frac{3}{32}$ inches apart. Lay the 45° triangle on the upper edge of the T-square and draw the topmost line of the sectioning. Then slide the triangle along the T-square for each successive line. As far as possible, draw both sides with one placing of the triangle. The sectioning should be inked in without previous penciling and the lines should be finer than the lines of the cylinder. Various devices are in use for mechanically equalizing the distances in section-lining, but the trained eye is the most practical method. When two abutting pieces are sectioned, the section-lining on one piece slants in an opposite direction to that on the other.

The right-hand drawing is that of a hollow cylinder with a flange about the top and bottom. In practice, when an object to be sectioned is the same on both sides of its centre line, only one side is sectioned while the other side is drawn in full. This method is here shown. In the front view, the part to the left is drawn in full and that to the right is drawn in section. The top view is drawn in full, as though the front view were not sectioned.

Construction lines are omitted in inking, therefore, upon this and succeeding sheets the construction lines are not shown.

HOLLOW CYLINDERS.

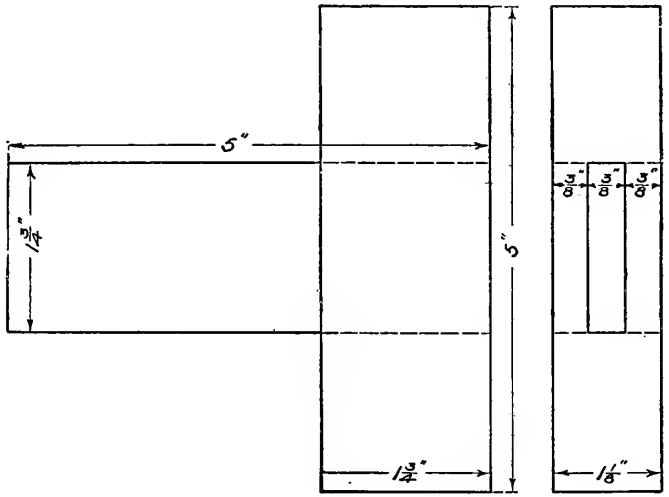


SHEET VI.

Mortise and Tenon Joint.

An application of some of the foregoing principles is here made in a simple working drawing of a mortise and tenon joint. A mortise $\frac{3}{8} \times 1\frac{3}{4}$ inches is cut in the centre of the end piece, into which a tenon cut upon the other piece, closely fits. This is clearly shown by the drawing.

MORTISE AND TENON JOINT.

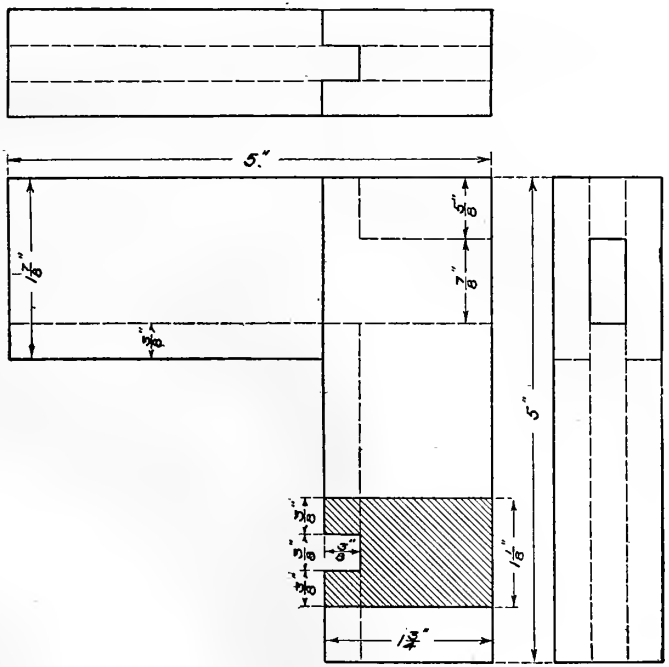


SHEET VII.

Door Joint.

A working drawing of a slightly more complicated joint is here shown. The front and side views are sufficient to make the joint from, but the top view is added to make the method of constructing the joint somewhat clearer. This joint is an end mortise and tenon joint and has a rabbet cut on the inside faces. The rabbet is shown by the section at the lower part of the drawing. The section illustrates a method commonly used for showing transverse construction. The material is supposed to be cut through at right angles to the face and the cut surface turned up until it lies in the plane of the face.

DOOR JOINT.



SHEET VIII.

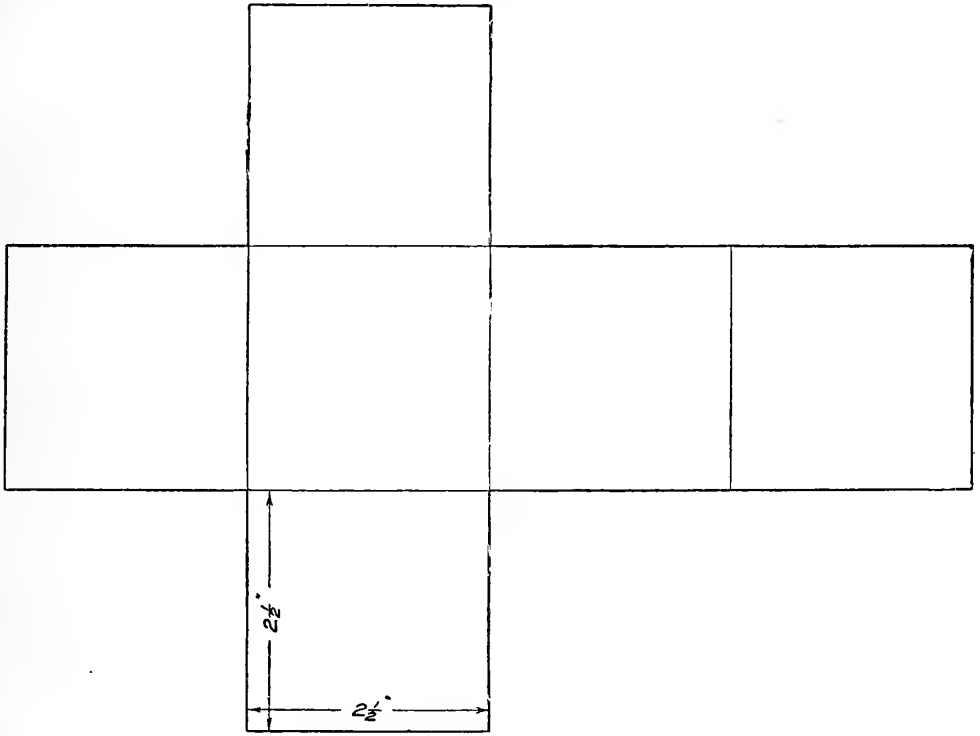
Development of Cube.

By the development of the surface of an object is meant the laying out of the pattern which, when properly folded, will exactly represent the surface of the object.

A simple and easily conceived development is that of a cube. It is necessary to know the dimensions of the faces and the number of faces, six. For example, let each face be $2\frac{1}{2}$ inches square. Draw a square to these dimensions and let it represent the front face. Immediately above and below draw the top and bottom faces, and at the left and right the side faces, and adjoining either side, add the back face. Such a drawing is here shown. If cut out and folded along the lines connecting the squares, the result would be a $2\frac{1}{2}$-inch cube.

An aid to a clearer comprehension of the principles involved in laying out patterns, and also a check to the accurateness of the work, may be obtained by duplicating this and the succeeding five patterns upon a sheet of thin card-board or stiff paper and folding to the desired shape. A lap, for pasting, should be added along outer edges.

DEVELOPMENT OF CUBE



SHEET IX.

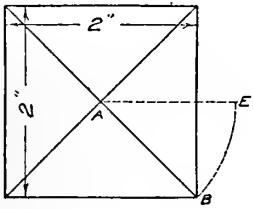
Development of Square Pyramid.

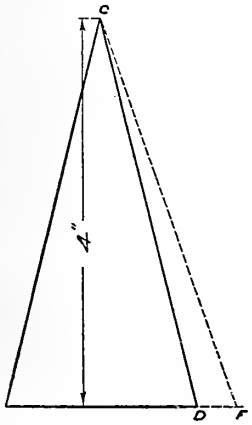
Draw the top and front views of a pyramid having a base 2 inches square and an altitude of 4 inches, and develop its surface.

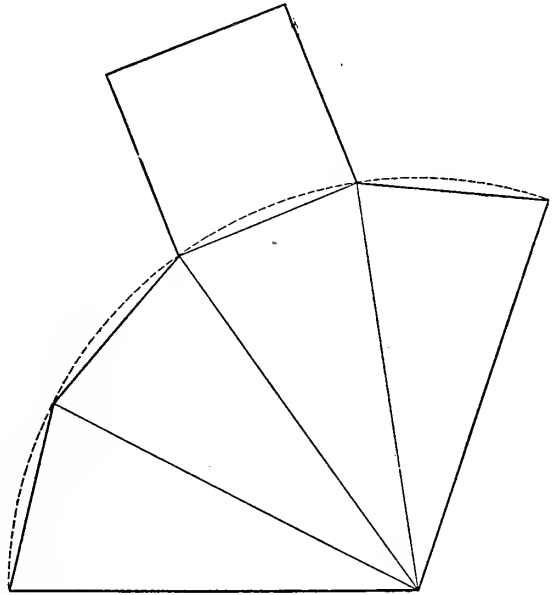
To obtain the development of the surface of the pyramid it will be necessary first to carefully study the two views. These show that the pyramid has four sides and a base, and that the sides are equal triangles successively joined together. All that is required, then, is to draw four equal triangles joined together about their vertices, and upon one of the triangles to join the square base. As two sides of the triangles are equal and meet in a point, they may be considered in the pattern as radii of an arc of a circle. The next step is to find the length of this radius. A top view of one of the sides of the face triangles is shown at A B, and a front view of the same line is shown at C D. But this front view of the line is foreshortened, and it is required to find its true length. Imagine the pyramid rotated about its axis so that the line A B would assume the position A E. Then the projection of this line in the front view is C F, which is the required true length. This exemplifies an important rule for developments, that the true length of each line must be ascertained, and also that the projection of the true length of a line will show as a horizontal line in a top view.

Having now found the true length of a side, C F, this length is taken in the compasses and an arc of indefinite length is described. From some point in this arc as a centre, and with a radius equal to a side of the base, an arc is drawn cutting the first arc. The two points are joined by a chord which represents the base of one of the triangles. This base line is laid off four times and the various points joined to the centre of the arc. Upon one of the chords a 2-inch square is drawn, completing the pattern.

DEVELOPMENT OF SQUARE PYRAMID.







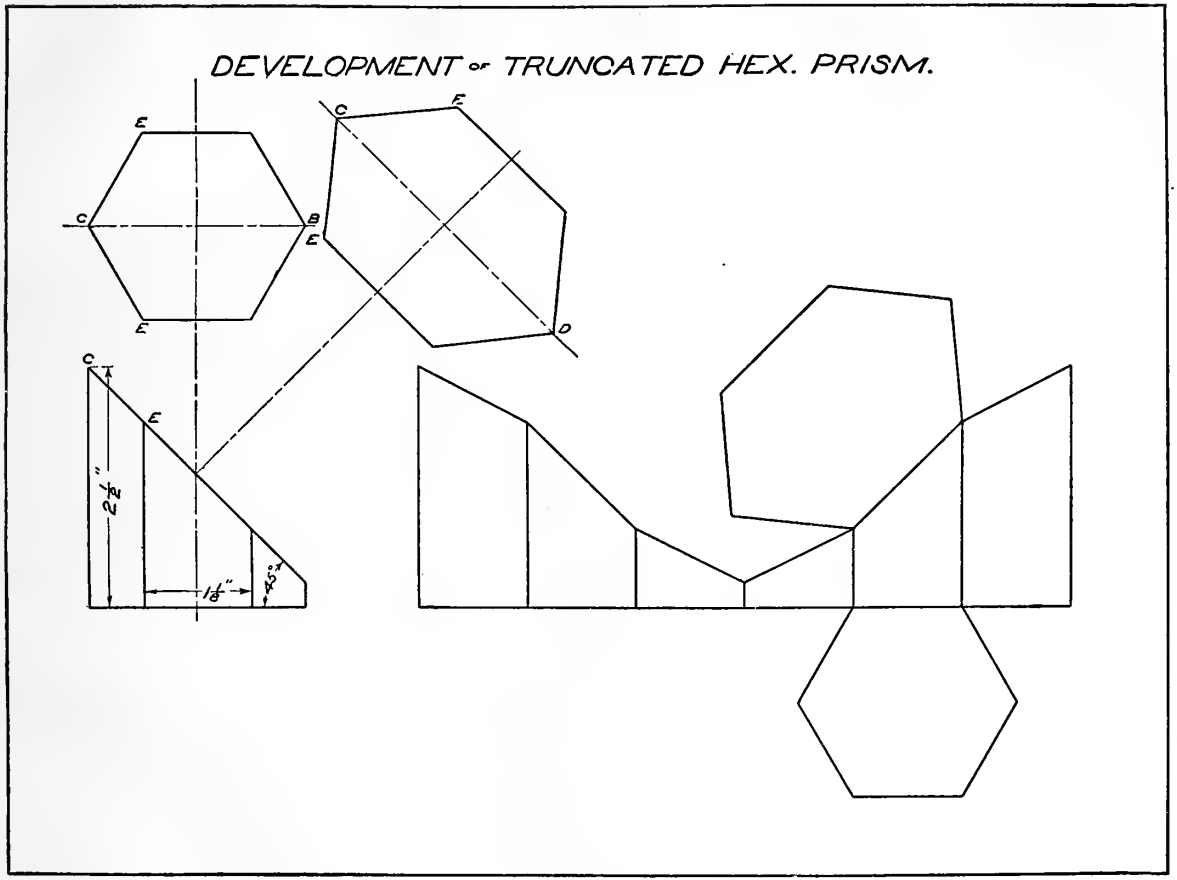
SHEET X.

Development of Truncated Hexagonal Prism.

Draw the top and front views of a hexagonal prism, each face of the hexagon being $1\frac{1}{8}$ inches, and at $2\frac{1}{2}$ inches from the base, measuring along the left-hand edge, pass a cutting plane making an angle of 45° with the base. Also develop the entire surface of the truncated prism thus formed.

As the sides of the hexagon are equal, their development is a line six times $1\frac{1}{8}$ inches long. Therefore, draw a line $6\frac{3}{4}$ inches long as the base line of the pattern, and for convenience in projecting, let it be in the prolongation of the base line of the prism. Divide this line into six equal parts, and at the points of division erect perpendiculars. On these lines cut off distances equal to the cut edges of the prism. This may be done directly by projection from the front view. Connect the tops of lines, and attach a regular hexagon to one of the sides. In order to find the true shape of the top it will be necessary to make a view at right angles to it in the front view. At right angles to the cut face draw a line, and at some point in it draw another line at right angles to it. This latter line is shown at C D. From C and E in the front view project lines at right angles to the cut, through C and E, E in the oblique view. As the point C is on the centre line in the top view, it will also be on the centre line in the oblique view. On the line projected from E in the front view, the positions of E, E must be determined. As the line C D is only another position of the line C B, the distances of E, E from C D and C B must be the same in both instances. The positions of these points being determined, together with that of C, the remaining points are obtained in a like manner and joined in their regular order.

It now only remains to transfer this true shape of the cut surface to the rest of the pattern. Select any side as a connecting side. Then, as any point is determined by its distance from any two other points, each of the corners may be located by two intersecting arcs, the radii of which are equal to the distances from any two points previously found.


DEVELOPMENT OF TRUNCATED HEX. PRISM.
E
C
B
E
E
C
E
D
C
E
2½"
1⅛"
⅝"

SHEET XI.

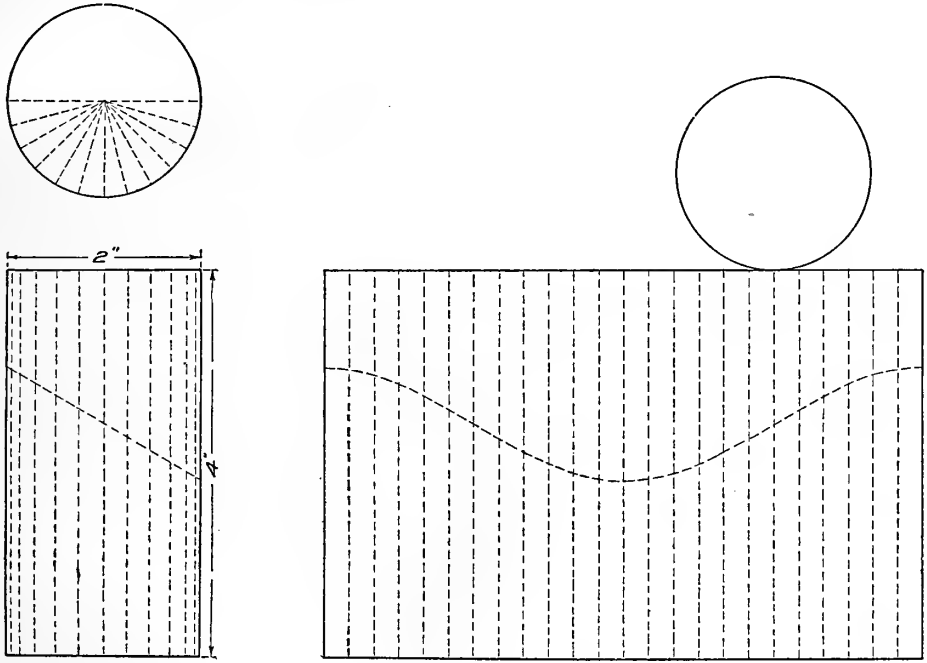
Development of Cylinder.

Draw the top and front views of a cylinder to the dimensions given, and develop the side and top surfaces.

As the circumference of a circle is 3.1416 times the diameter, the development of the side of the cylinder would be a rectangle 3.1416 times 2 inches long and 4 inches wide. The customary practice, however, is to divide the top view into a number of equal parts and step off with the dividers the same number of equal parts for the development. In the drawing, one-half of the top view is shown divided into twelve equal parts, therefore twenty-four of the parts are laid off along the base line of the pattern. The divisions of the top view are projected along the front view as elements of the cylinder, and these elements are reproduced on the pattern when it is desired to show the development of a cut. A supposed cut is here shown in the front view by a construction line, and its development is shown on the pattern. Imagine the elements of the cylinder numbered from left to right and the elements of the pattern correspondingly numbered. Then, with the T-square, project the intersection of the first element of the cylinder with the cut, across to the first element of the pattern. The intersection of the second element with the cut is next projected to the second element of the pattern, and so on till the centre element of the pattern is reached. As the cut is the same at the back of the cylinder as in front, the right-hand side of the developed curve will be identical with the part already found, only reversed. Draw the curve in free-hand with pencil, and ink with the aid of the scroll.

The true shape of the face of the cut is an ellipse, and may be found by the method shown in the previous sheet, for finding an oblique view.

DEVELOPMENT of CYLINDER.



SHEET XII.

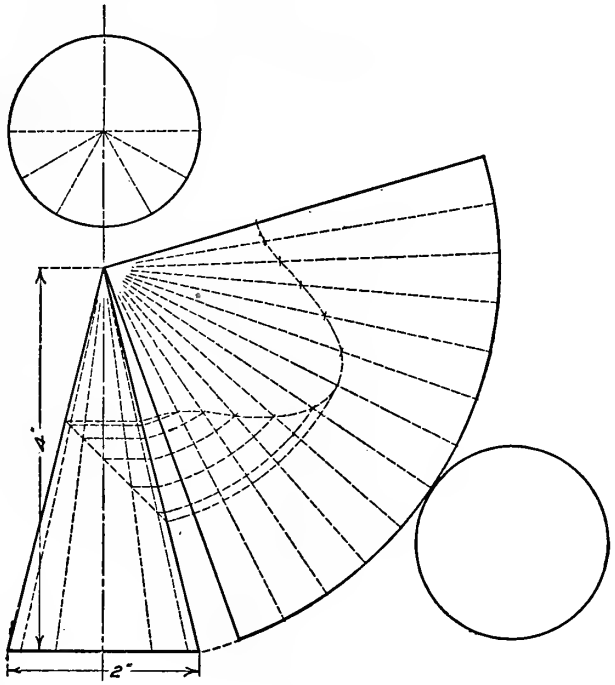
Development of Cone.

Draw the top and front views of a cone having a 2-inch base and an altitude of 4 inches, and develop its surface.

As in the case of the cylinder, divide the circumference in the top view into a number of equal parts and project these divisions upon the base line of the front view. Connect these projected points with the apex of the cone. To the right of the cone describe an arc, having a side of the cone as radius and the apex as centre. On this arc lay off the development of the circumference in the top view by stepping off the same number of equal parts as there are divisions of the circumference. Connect each of the points stepped off with the apex. By drawing a circle equal to that of the top view, tangent to the arc, the pattern of the cone is completed.

If it is required to obtain the development of the frustum of a cone, the cut may be developed in the manner shown in the drawing. From the points of intersection of the cut with the various elements of the cone draw lines parallel to the base, cutting a side line. The true lengths of the cut elements are thus obtained. With the apex as centre, and with radii equal to the distances to each of the points found on the side line of the cone, describe arcs cutting the elements of the developed cone. The process is identical with that used in developing the cut of the cylinder, excepting that the points are projected by concentric arcs in the case of the cone and by parallel lines in the case of the cylinder. As in the previous sheet, the true shape of the cut face is an ellipse, and may be found by the method there indicated.

DEVELOPMENT OF CONE.



SHEET XIII.

Development of Four-Piece Elbow.

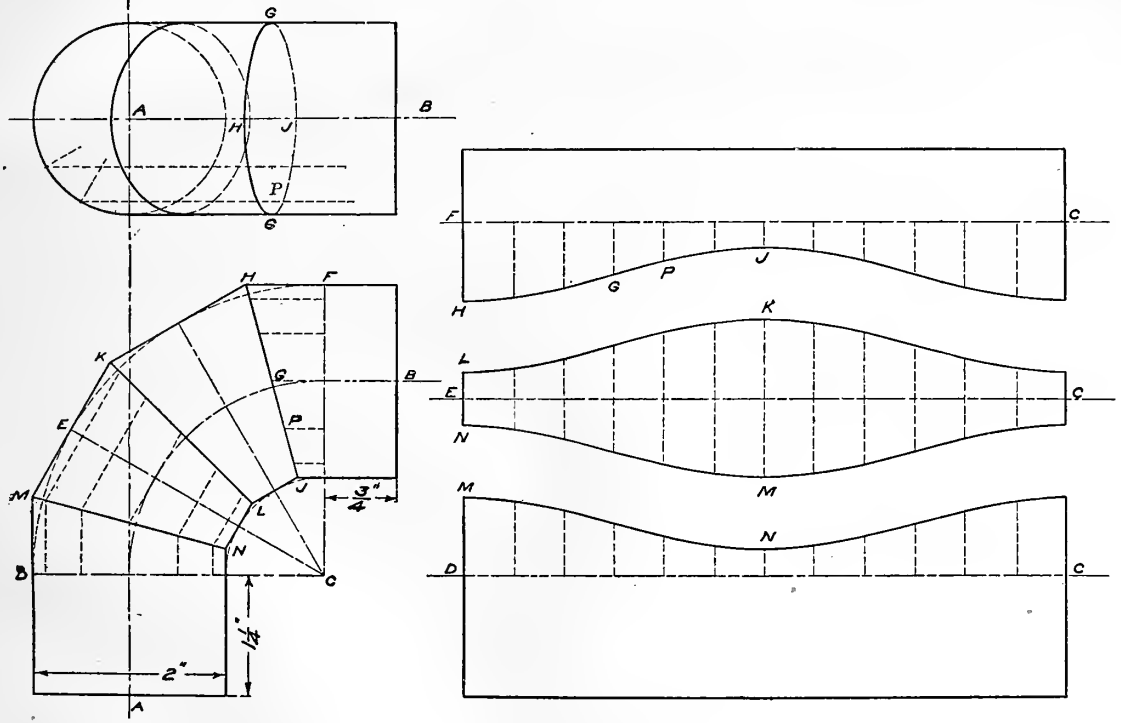
Draw the top and front views of a four-piece elbow, together with its development.

The ellipses in the top view are obtained by projecting the points of intersection of the joints in the front view with the elements, to corresponding elements in the top view. Five such points are shown at G, H, G, P and J. The top view is not required in obtaining the development, and is given only as an additional exercise in drawing. First draw a 2-inch cylinder of indefinite height. At $1\frac{1}{4}$ inches above the base draw a horizontal line D C, extending it to the right, one inch beyond the cylinder, and erect the perpendicular, C F. With the 30°-60° triangle divide the right angle thus formed into three equal angles. The sides of these angles serve as centre lines for the various parts of the elbow, and their bisectors, H J, K L, M N, are the joints. The angles may be bisected by stepping off two equal divisions on the quadrant serving as the centre line of the elbow. The joint M N, crossing the cylinder as first drawn, completes the lowest part of the elbow. To obtain the second part, draw lines from the extremities of M N, at right angles to E C, until cut by the second joint K L. The remaining parts are obtained by the same method.

The development of the lowest part is obtained as shown in **Sheet XI.** The two central parts are alike, therefore one pattern will suffice. Draw a horizontal line E C, corresponding to the centre line E C, in the front view. Cut off distances above and below the centre line of the pattern equal to the distances above and below E C in the front view: *e. g.*, L N and K M. Connect the points found by a smooth curve. The upper part is obtained by stepping off the distances from corresponding elements of the upper part in the front view. Similar letters refer to similar points in each of the views.

The distance that the point C is from the elbow determines the curvature of the elbow; the nearer the point, the sharper the turn.

DEVELOPMENT OF FOUR-PIECE ELBOW.



SCREW THREADS.

In the figure opposite, let A B C D represent a cylinder, and let the base line, D D, of the triangle be equal to the circumference of the cylinder. Imagine the side B D of the triangle placed against the element B D of the cylinder, and the triangle wrapped around the cylinder. The hypotenuse of the triangle would then present the appearance shown by the curve. Such a curve is called a *helix*, and the perpendicular distance between the ends of the curve is known as its *pitch*.

Another way of imagining a helix to be traced is by a point rotating about a centre and at the same time advancing in a straight line. This is clearly shown on a screw-cutting lathe in which the metal to be cut revolves with a uniform velocity and the tool is fed along a straight line parallel to the axis of the screw.

It is customary to speak of pitch as the number of threads per inch rather than by the true pitch measurement. A thread of one-eighth-inch pitch is known as "8-pitch"; that is, there are eight threads to the inch.

The following table is one that draughtsmen should be familiar with:

SELLERS' OR U. S. STANDARD SCREW THREADS.

Diam.	*Pitch.*	*Diam.*	*Pitch.*	*Diam.*	*Pitch.*	*Diam.*	*Pitch*
$\frac{1}{4}$	20	$\frac{13}{16}$	10	$1\frac{1}{2}$	6	$2\frac{1}{2}$	4
$\frac{5}{16}$	18	$\frac{7}{8}$	9	$1\frac{5}{8}$	$5\frac{1}{2}$	$2\frac{3}{4}$	4
$\frac{3}{8}$	16	$\frac{15}{16}$	9	$1\frac{3}{4}$	5	$2\frac{13}{16}$	$3\frac{1}{2}$
$\frac{7}{16}$	14	1	8	$1\frac{7}{8}$	5	3	$3\frac{1}{2}$
$\frac{1}{2}$	13	$1\frac{1}{16}$	7	$1\frac{15}{16}$	5	$3\frac{1}{4}$	$3\frac{1}{2}$
$\frac{9}{16}$	12	$1\frac{1}{8}$	7	2	$4\frac{1}{2}$	$3\frac{5}{16}$	$3\frac{1}{4}$
$\frac{5}{8}$	11	$1\frac{1}{4}$	7	$2\frac{1}{4}$	$4\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{4}$
$\frac{11}{16}$	11	$1\frac{5}{16}$	6	$2\frac{5}{16}$	$4\frac{1}{2}$	$3\frac{3}{4}$	3
$\frac{3}{4}$	10	$1\frac{3}{8}$	6	$2\frac{3}{8}$	4	4	3

The standard thread in the United States is known as the Sellers' thread. The angle of this thread is 60 degrees. One-eighth of the top of the thread is taken off and an equal amount added to the bottom, thus doing away with the sharp corners. A section of the Sellers' thread is shown in **Sheet XIV,** and also a section of a square thread.

Screw Threads.

HELIX AND PITCH.

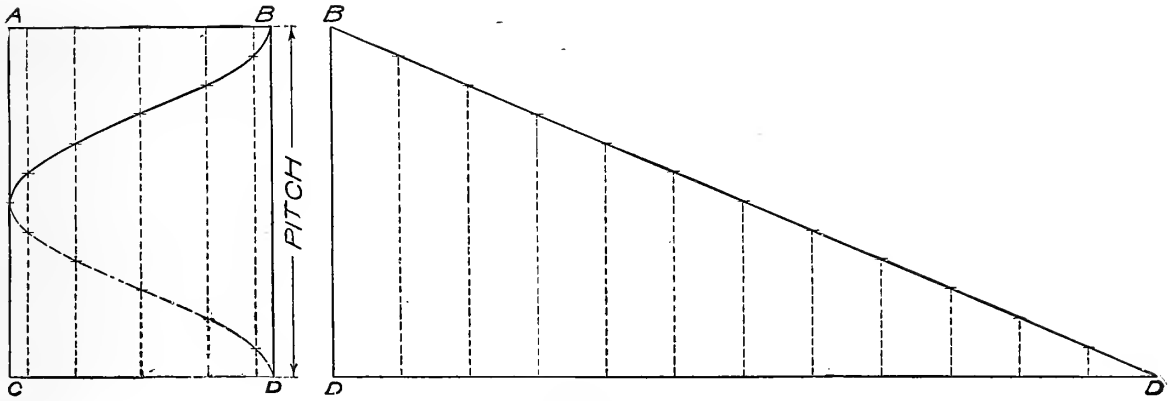


FIG. 3.

SHEET XIV.

Screw Threads.

At the upper left-hand corner of the sheet is shown the method of obtaining the curve of a screw thread. Divide one-half the circle into any number of equal parts and divide one-half the pitch A H into the same number of equal parts, say six. Then project the points of division of the circle successively to the lines of division of the pitch, as A to A, B to B, C to C, etc. Connect the last series of points by a smooth curve. The root curve is obtained in a similar manner from the points of division on the inner circle. Observe that in a single-threaded screw the point on one side is directly opposite the root on the other.

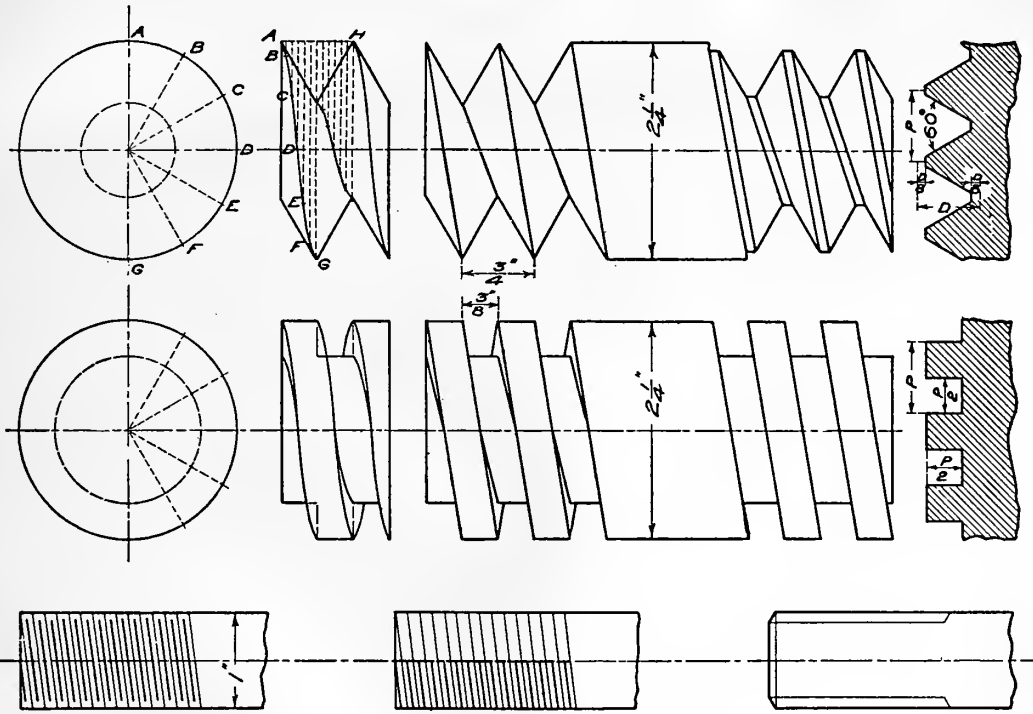
To draw the square-threaded screw, shown in the centre drawing, lay off the pitch along the sides and sketch in lightly the squares representing the depth and width. The curves are obtained as in the case of the V-thread. Notice that part of the curves are hidden, and draw only such parts as appear in the front view.

The method of representing screw threads just explained is not used in working drawings, because of the amount of time and trouble it necessitates, and because the object of the drawing can be attained as well by a much simpler method.

Various kinds of conventionalized threads for small screws are shown at the lower part of the sheet. That shown at the left is a common method. The longer lines represent the tops of the threads and are drawn about one-eighth of an inch apart, regardless of what the pitch may be. The shorter lines are drawn slightly heavier and not quite to the sides of the thread.

At the top of the sheet straight lines are substituted for the curves of the V-thread, and at the right the thread is given a more finished appearance. In the centre of the sheet are shown two methods for drawing conventional square threads.

SCREW THREADS.



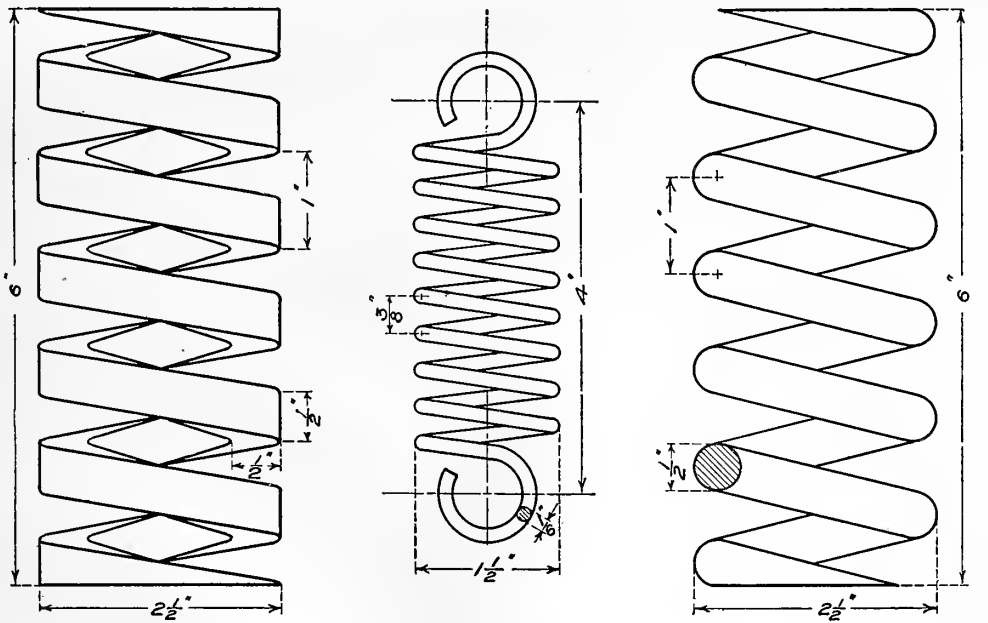
SHEET XV.

Springs.

This sheet shows conventional methods of representing springs. The spring at the left may be considered as a square-threaded screw from which the body has been removed. The curves, except at the ends, are shown as straight lines

The two springs at the right are of round wire, sections of which are shown. Draw circular arcs with centres an inch apart for the larger spring and three-eighths of an inch for the smaller one. Draw lines tangent to these arcs.

SPRINGS.



SHEET XVI.

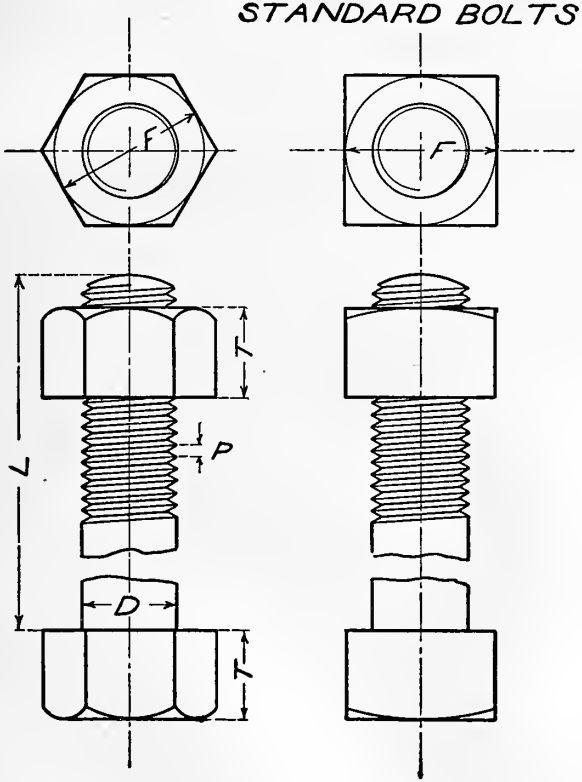
Standard Bolts and Nuts.

This sheet is designed to show the proportions of standard bolts and nuts. The diameter of the bolt is the unit from which the various proportions are derived. In the drawing, the diameter of each of the bolts is taken as one inch. The lengths of the bolts are shown as indefinite. Complete the drawing to the standard proportions for finished bolts and nuts given in the Table, page 38.

To draw the chamfer on the hexagonal nut or head, take a radius equal to the thickness of the nut and with centre at the intersection of the centre line and bottom of nut, describe an arc. The intersections of the arc with the sides of the front face determine the extremities of the two side arcs. By trial, find a point on the centre line of the side face for an arc passing through the top of the nut and the two extremities before determined. The point is about one-quarter way down the centre line. The chamfer on the square nut is here shown as equal to that on the hexagonal nut.

A hexagonal nut may be drawn with close approximation to accuracy by the following method, which dispenses with the drawing of the hexagon: First draw the centre line of the nut, and then the top and bottom lines equal to the diameter of the bolt. Draw the front face slightly narrower than this diameter, and take the width of each of the side faces as equal to one-half the front face. Add the chamfer, as above. Three faces of a hexagonal nut should be shown, and but one face of a square nut.

STANDARD BOLTS AND NUTS.



	ROUGH	FINISHED
F	$1\frac{1}{2}D+\frac{1}{8}$	$1\frac{1}{2}D+\frac{1}{16}$
T	D	$D-\frac{1}{16}$

D = Outside diam of bolt

F = Short diam of head or nut

T = Thickness of head or nut

L = Length of bolt

P = Pitch.

$\frac{1}{p}$ = No. threads per inch

SHEET XVII.

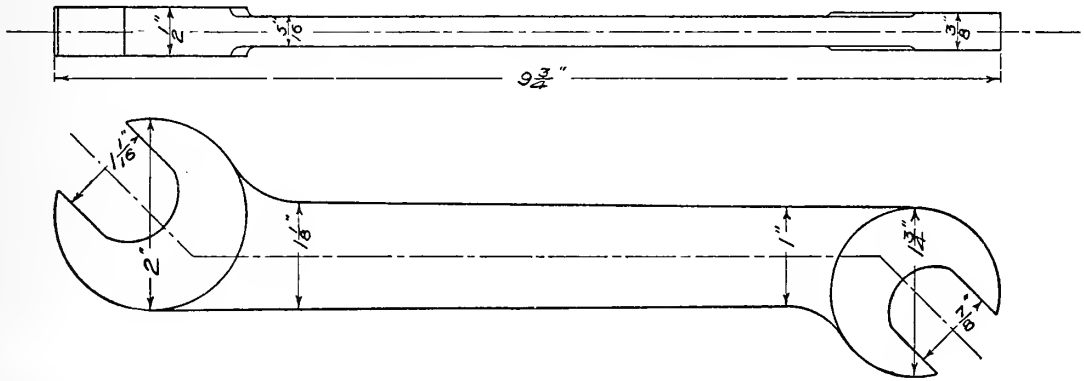
Spanner Wrench. — Drop Forged.

It is desirable that objects somewhat similar to those shown in this sheet and the sheets immediately following, be used as models. Where this is impracticable, the drawings may be used as sketches. When a drawing is to be made from the object, a pencil sketch is first made. All sketches should be free-hand and carefully executed. The dimensions are taken from the object with foot-rule and calipers.

Care should be exercised in the placing of dimensions. No general rule can be laid down, as the proper dimensioning of a drawing is a matter of experience. The draughtsman should be familiar with machine-shop practice, and put such dimensions on his drawings as best serves the purpose of the workman.

This sheet shows a working drawing of a spanner-wrench, drop forged. All the curves are arcs of circles, the centres of which it will be necessary to locate. Draw to the dimensions given. In making working drawings, first locate the centre lines and build the drawings up about them. The figures used in dimensioning should be about one-eighth inch in height, and be strong and distinct. In inking, put in all curves first and then the straight lines.

WRENCH=DROP FORGED.

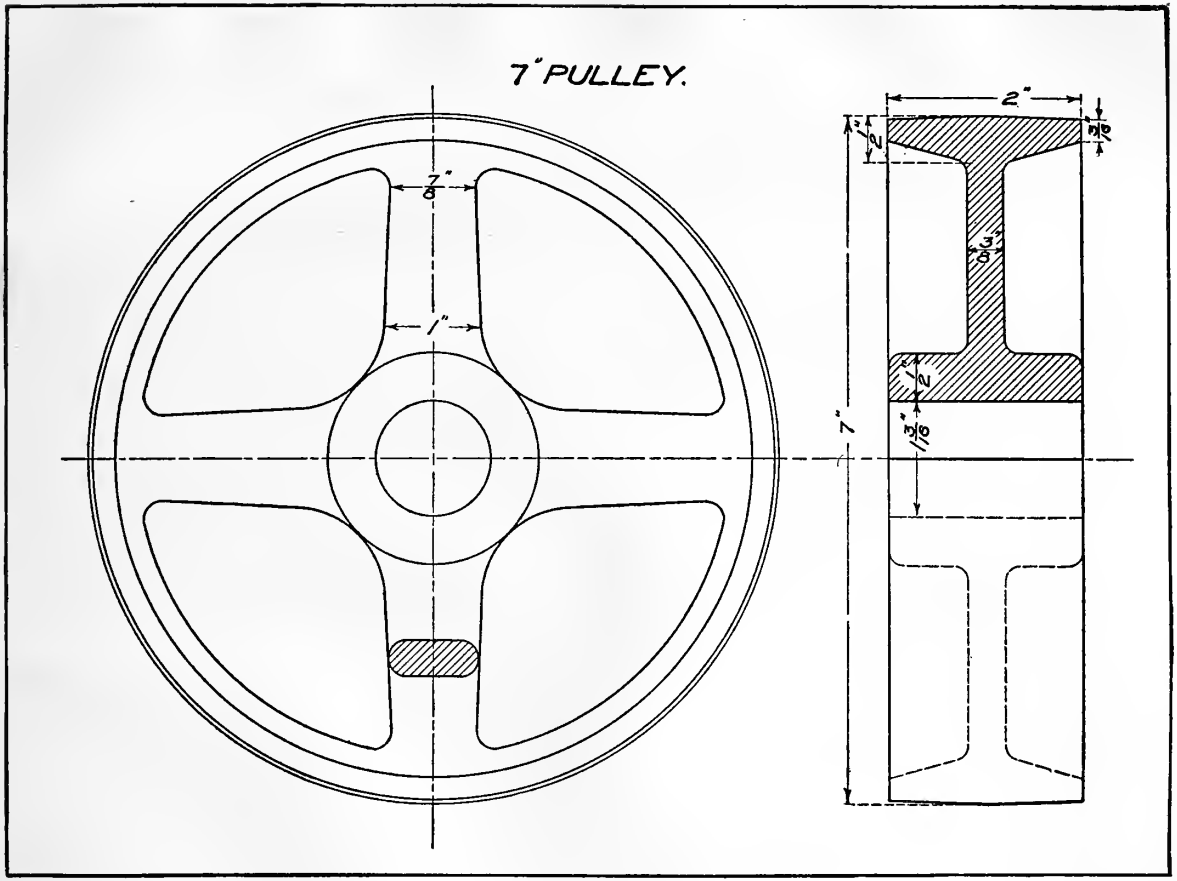


SHEET XVIII.

Seven-inch Pulley.

In **Sheet V** we learned that "when an object to be sectioned is the same on both sides of its centre line, only one side is sectioned, while the other side is drawn in full." In this sheet is found an application of this rule. The pulley is symmetrical about the centre of the shaft, therefore, in sectioning, one-half alone is shown. The lower half of the pulley is in outline, though the drawing would be quite as serviceable without the hidden lines.

As many dimensions as possible should be given on one view. The same dimension should not be repeated. Where a dimension is given on a sectioned surface, the section-lining should not cross the figures. Do not crowd the figures. Where there is not room for both the figures and the arrow-heads between the lines to be dimensioned, the arrow-heads may be placed outside the lines, as shown at the upper right-hand corner of the sheet. See that all unfinished corners of castings are rounded. Draw to the given dimensions. To show the structure of a part, a cross-section is sometimes placed on the part, as shown on one of the spokes.


7" PULLEY.
2"
3/8"
1/2"
3/8"
7"
1"
1/2"
1/2"
1 3/16"

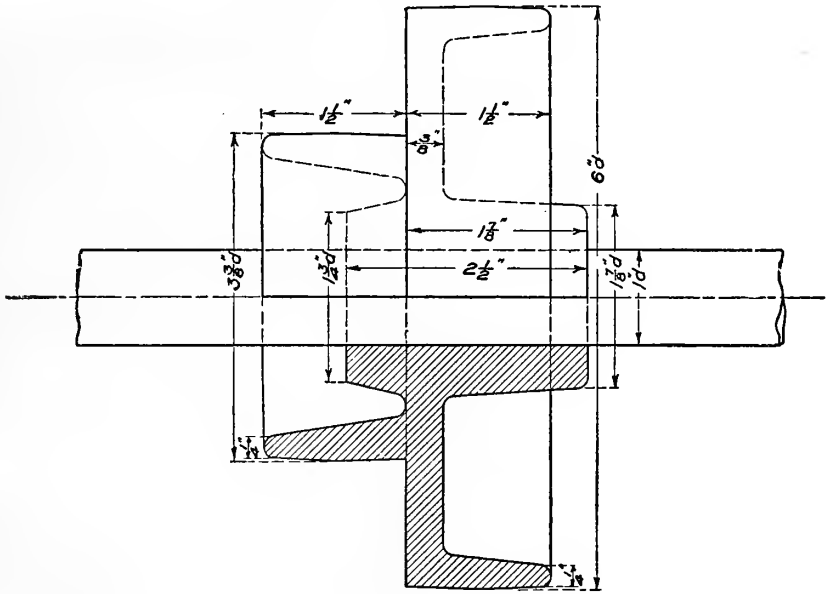
SHEET XIX.

Cone Pulley.

When an end view of an object shows only circles, it should be omitted. Therefore, but one view of the cone pulley is necessary. The fact that an end view would show as a series of concentric circles may be expressed by placing the abbreviation "d," or "dia." after the dimensions that show diameters.

Shafts should not be sectioned. Spindles, studs nuts, bolts and screws are also included in this rule. An application of the rule is given in the drawing, where the shaft is shown in full, while the pulley is shown in section.

CONE PULLEY.

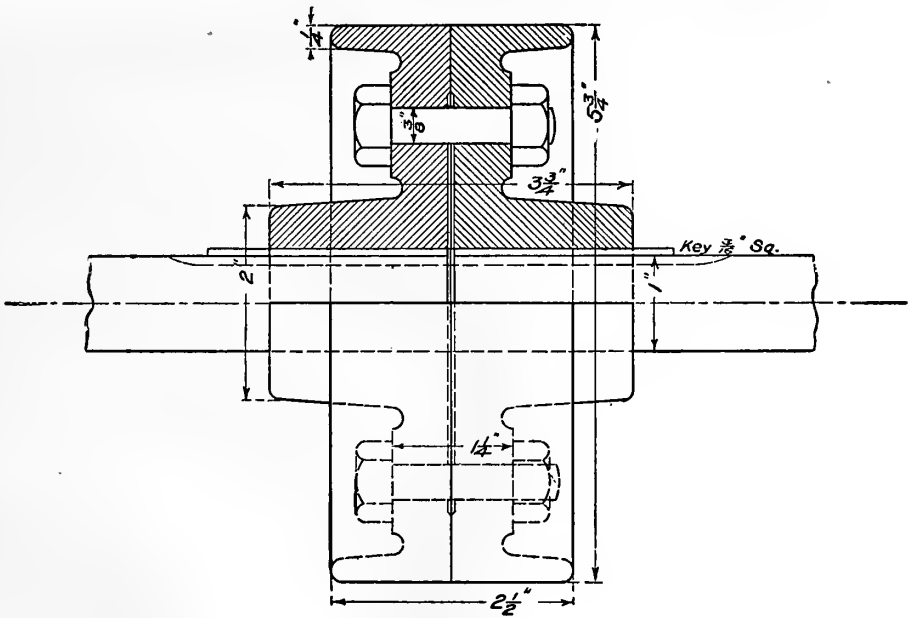


SHEET XX.

Flange Coupling

The rule to which attention was called in the last sheet, that shafts should not be sectioned, is further emphasized in this sheet, wherein not only the shaft is not sectioned, but also the bolt and nut. When two adjacent pieces are sectioned, the section-lining takes a different direction in each.

FLANGE COUPLING.

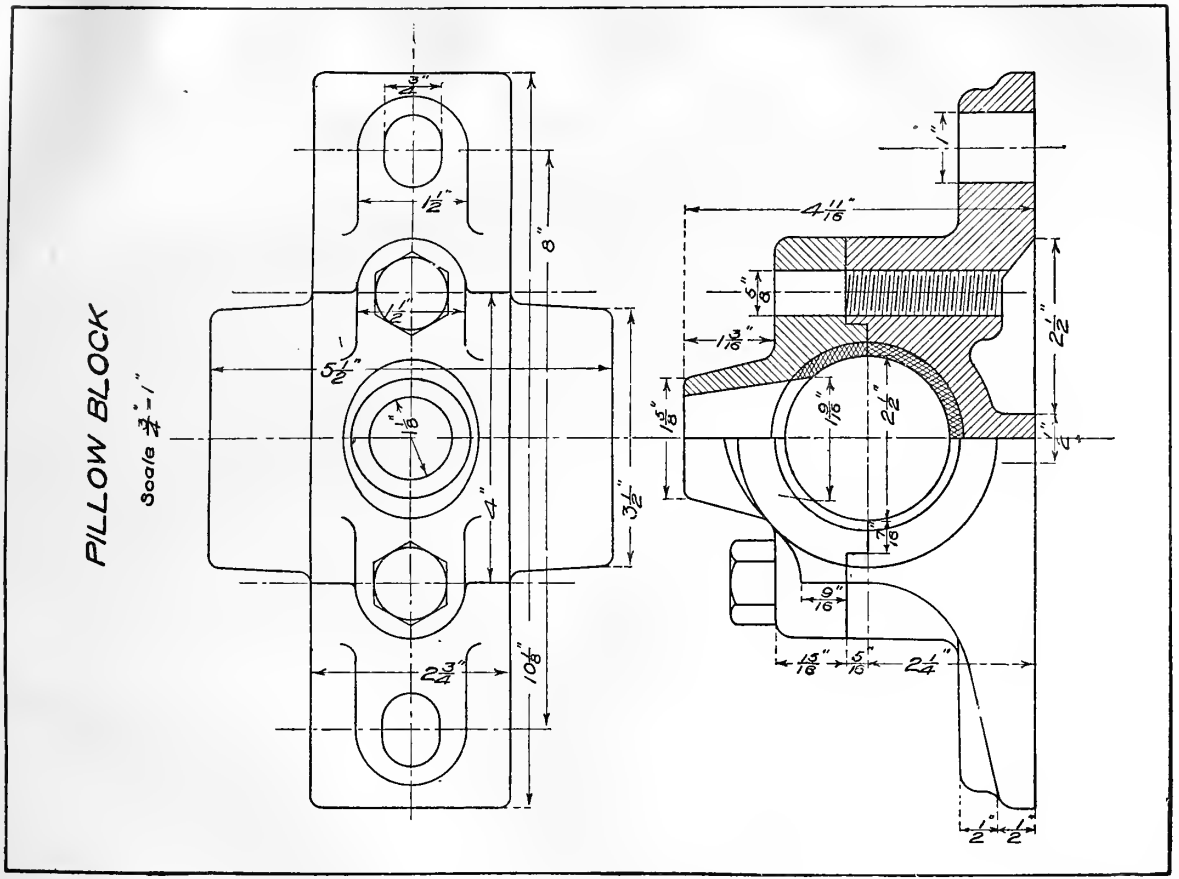


SHEET XXI.

Pillow-Block.

As a full-size drawing of the pillow-block to the dimensions given would be too large for the sheet, it becomes necessary to draw it to a reduced scale. The scale should be as large as possible; in this case, three-quarters of an inch to the inch. That is, for each inch measured upon the pillow-block, three-quarters of an inch is drawn. The dimensions should in all cases be the full dimensions of the object. Place a note upon the drawing, stating the scale to which it is drawn when other than full scale. Centre line all holes and give the distance between centres.

An endeavor has been made to adopt a standard section-lining to represent different materials. A section-lining to represent Babbitt-metal is here shown. It consists of lines drawn at 30° or 60° in both directions. The purpose of such section-lining is generally more easily and satisfactorily obtained by giving the name of the material in a note upon the drawing.

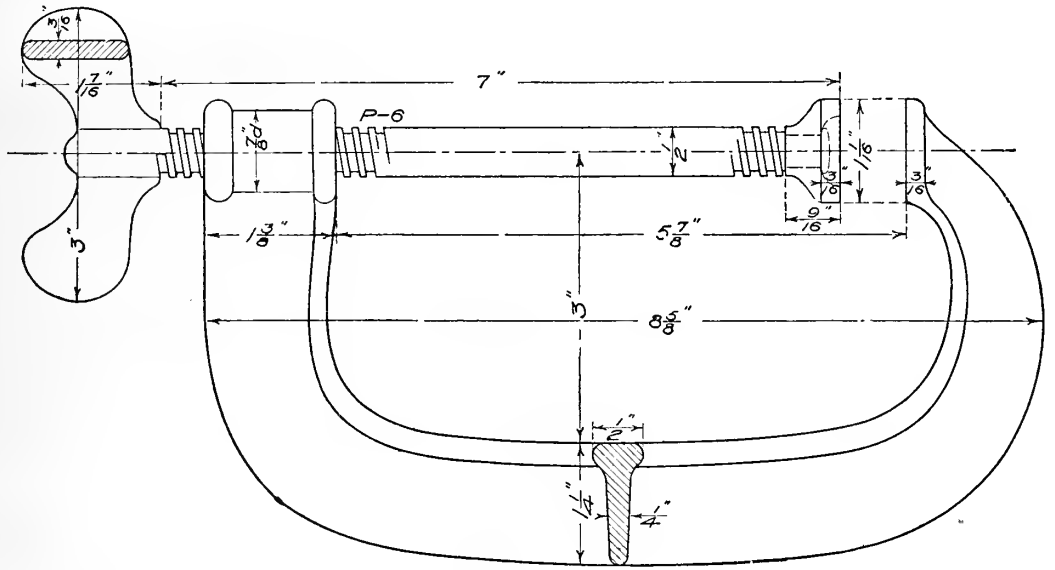

PILLOW BLOCK
Scale 1/4 = 1"
3/8"
1 1/2"
1 1/2"
5 1/2"
1 3/8"
8"
4"
3 1/2"
2 3/4"
10 1/8"
1"
4 11/16"
5/8"
1 3/16"
1 5/8"
1 3/16"
2 1/2"
2 1/2"
1/2"
9/16"
7/16"
9/16"
1 5/16"
5/16"
2 1/4"
1/2"
1/2"

SHEET XII.

Five-inch Clamp.

In long screw-threading, considerable time may be saved by drawing the threads at the beginning and ending only. This practice is shown on the drawing of the clamp. The necessity for an end view is obviated by showing in section such construction of parts as would be shown in the end view.

5 IN. CLAMP.



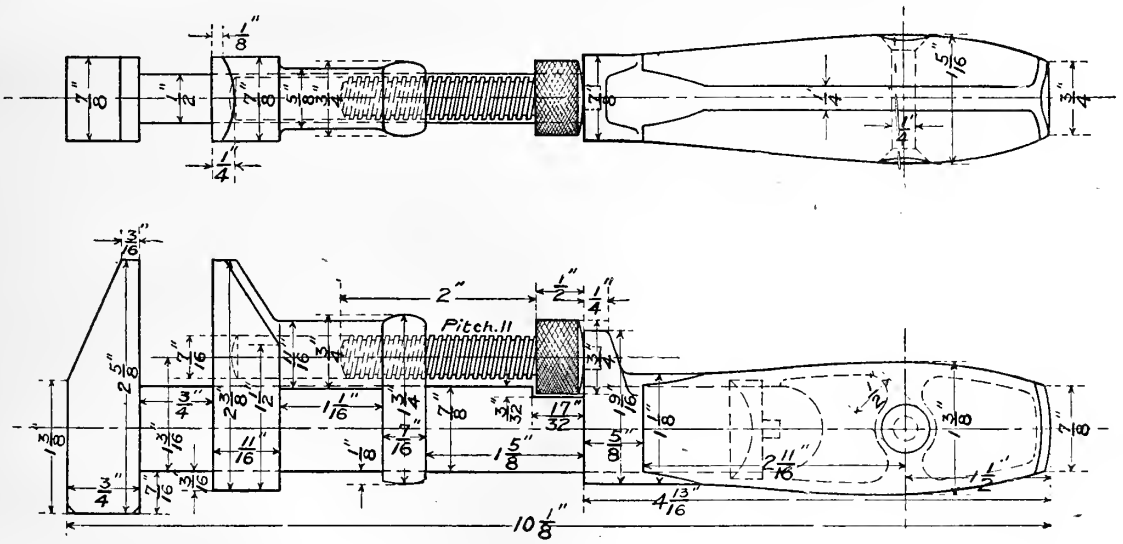
SHEET XXIII.

Monkey Wrench.

The pitch of the thread is here given in a note on the drawing as "Pitch-11"; it might be abbreviated to read "P-11." If the thread is a left-handed one, it is so noted on the drawing, otherwise it is understood to be right-handed. A single-thread is understood unless otherwise noted.

A scheme for putting in small dimensions is shown in the case of the topmost dimension on the sheet Two arrow-heads embrace the part to be dimensioned and the shaft of one of the arrows serves as the division-line of the fraction. The interior construction of the handle is here suggested, but not dimensioned. The cross-hatching indicates the knurling of the head of the bolt.

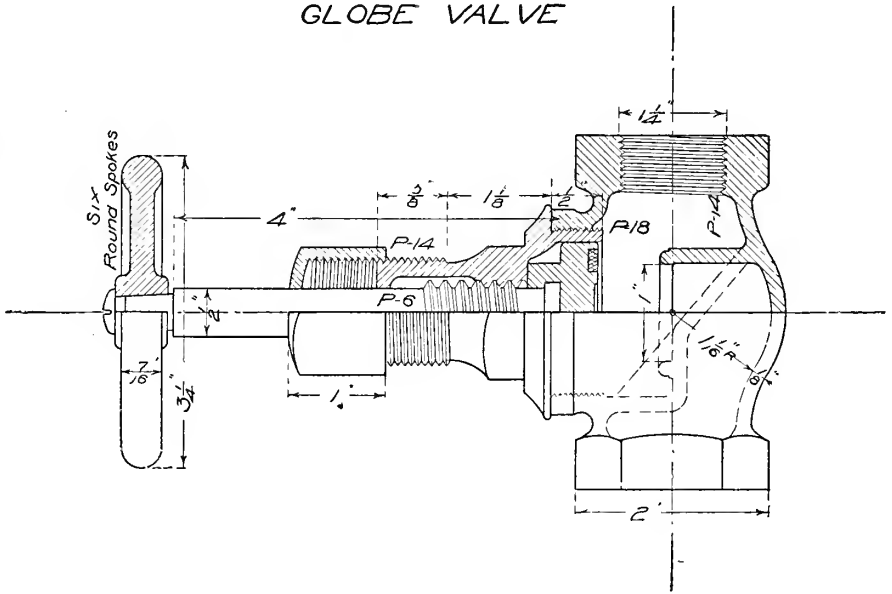
MONKEY WRENCH.



SHEET XXIV.

Globe Valve.

The valve is symmetrical about its centre-line, excepting the construction of the valve seat. One-half is in section and the left-hand side of the valve is shown by hidden lines. Another method of showing the valve seat is to break away a piece of the wall and show the entire valve seat in section. To avoid crowding, some of the minor dimensions are omitted in the drawing.


GLOBE VALVE
Six Round Spokes
4"
3/8"
1 1/8"
1/8"
1 1/4"
P-14
P-18
P-14
P-6
1"
1/2"
1/16"
3 1/4"
1"
1 1/16" R
2"

NOTES ON WORKING DRAWINGS.

GENERAL DIRECTIONS.

PRACTICE in the various draughting rooms may differ in details, yet is uniform in principles. These principles we have been studying in the previous sheets of this course, and are about to apply them in making a complete set of working drawings of a bench lathe. For the sake of compactness, and the arranging of a series best adapted for students' use, the set is made up of five sheets, the first of which is an assembly drawing, that is, a drawing showing the assembling of all the parts into the complete machine, and the remaining four being each a detail sheet of the four parts of the lathe, head-stock, tool-rest, tail-stock, and bed.

Other arrangements of sheets might advantageously be made; *e. g.*, all work for the forge-shop might be grouped together, and also all work for the pattern-maker. In fact, it is the custom in some draughting rooms to make separate drawings for the machinist, the pattern-maker, and the blacksmith. Or all work required to be done on a certain machine, as a screw-cutting lathe, may be brought together.

For convenience in reference, the various points to which attention has been called in the sheets immediately preceding are here brought together under appropriate headings, and such notes are added as may be required for a comprehensive knowledge of prevailing draughting-room practice.

1. SIZE OF SHEETS. Some system of uniform sizes of sheets is generally adopted in draughting-offices to facilitate handling and filing. A convenient system permits of

a smaller sheet being made by halving the next larger. Such a scheme has been followed in this series. The paper comes in sheets, 22 x 30. Each sheet is cut into two sheets of 15 x 22, for large drawings, and again divided into sheets of 15 x 11 for the smaller drawings. The lathe drawings are made upon the larger sheets. The border-lines inclose a "sight" of $19\frac{1}{2}$ x 13. Trim to $\frac{3}{4}$ of an inch at the top, bottom and right-hand sides. A wider margin at the left permits of binding together the series of drawings.

2. TITLE, INDEX, ETC. Leave a space of 4 x 2 in the lower right-hand corner for title, etc. A method for titles is shown on the sheets. It consists of five parts:

a—Name of Machine.
b—Detail.
c—Scale.
d—Date and Draughtsman.
e—Index of Drawing.

The letter of the Index should, if possible, bear some relation to the machine designated, *e. g.*, L-Lathe. The first number is used to distinguish between various types of similar machines. The final number is the particular mark of the machine bearing it. In a complete set of drawings the assembly drawing should be indexed as number one, and should contain a list of the other drawings with their numbers.

The heights of the letters in "*a*" and "*b*" are $\frac{3}{16}$ inches for capitals and $\frac{1}{8}$ inch for lower-case letters. Other letters and figures are $\frac{1}{8}$ inch in height, excepting the index. Index letters and figures, *e. g.*, L-2-1 are $\frac{3}{8}$ inches high.

The firm's name should appear somewhere on each drawing. A common usage is to put this on with a stamp which sometimes includes the date.

3. SKETCHES. Sketches should be made with care and be of such a nature that a

correct drawing or even the thing itself could be made from them by another, if necessity demanded it. A pad of manila paper, about 8 x 12, will be found handy for making sketches. The work should be free-hand.

4. Laying out Work. Large sheets requiring considerable time may be stretched; otherwise use tacks.

Select such views as will best show the object and as few as will show it clearly.

Find approximately the space each view will occupy and locate centre-lines.

Build up each part about its centre-lines, not completing each view separately, but projecting lines from one view to another.

5. Relation of Views. Where more than one view is required, place the top view above the front view, the right view to the right, and the left view to the left. When an end view shows only circles, this view should be omitted, and the letter "d," or "dia." be used in dimensioning.

6. Sectioning. When it is desirable to show in detail the internal structure, sectioning should be used.

When an object is symmetrical about its axis, section but one-half.

Do not section bolts, nuts, screws, studs, spindles, and shafts.

The part of an object back of a sectioned view need not be shown.

Two adjacent cut surfaces should be sectioned-lined in opposite directions.

More than two cut surfaces may be distinguished by varying the width of the section-lining, or its slant.

7. Inking. If original drawings are to be inked, use black ink only. It is sufficient, however, to have the original drawing in pencil, as a tracing can be made directly from it.

Show centre-lines by light dashes, alternately $\frac{1}{2}$ and $\frac{1}{8}$ inches in length.

Show invisible parts by hidden lines made up of dashes about $\frac{3}{16}$ inches long.

Construction lines should not be inked.

Ink all curved lines first; then the straight lines.

When lines radiate from a point, stop them before reaching the point, to avoid blotting.

Keep the pens sharpened.

8. DIMENSIONING. Put in dimensions after the drawing proper is completed.

All dimension figures to be, at least, a scant eighth-inch, and made to read, in horizontal dimensions from the bottom of the sheet, and in vertical dimensions from the right of the sheet.

The division line of fractions should have the same direction as dimension lines.

See that the arrow-heads rest against the lines dimensioned.

Do not use centre-lines for dimension lines.

Give dimensions in inches and fractions of an inch up to 24 inches. Above 24 inches use feet and inches, always indicating feet and inches, separated by a hyphen, thus: 5′- 0″, which reads five feet, no inches.

When the dimensions are in even feet, the inches should always be expressed by 0″.

Give each dimension once only, regardless of the number of views.

Give dimensions over-all, that is, give the dimension of the whole in addition to the dimension of the parts.

As far as possible confine dimensions to the one view.

Designate a radius by "r" or "rad." and indicate the centre by a small circle.

The full dimensions should be given regardless of the scale of the drawing.

Dimensions should be placed upon the object, but where this would lead to crowding, the dimension may be placed adjacent to the object and connected by dashes.

Give distances between centres of bolt holes.

9. TRACINGS. Centre and dimension lines on tracings may be represented by full red-ink lines. The arrow-heads should be black.

Washes or crayon used for sectioning should be placed on the reverse side of the cloth.

If the ink does not readily adhere to the cloth, the surface may be brushed with chalk or talc.

10. GENERAL NOTES. Use explanatory notes freely.

"Finish" may be indicated by an "f," the cross-bar of the f being on the line to be finished. Or "finish" may be indicated by drawing a line in red ink adjacent to the surface to be finished.

The name of each piece and the number required for each complete machine should be marked directly over the piece.

In long screw-threading show only the beginning and ending of the thread.

A long object having the same construction throughout a considerable distance may be drawn with its central part broken out.

Do not use the scale as a ruler.

BLUE-PRINTING.

It is in the form of blue-prints that the drawings generally reach the shops. The prints are made by exposing chemically prepared paper to the action of the sunlight, and then washing in water.

Prepared paper may be purchased from dealers in draughtsmen's supplies, or it may be easily made as wanted. The chemicals required for sensitizing the paper are Citrate of Iron and Ammonia, and Red Prussiate of Potash. These may be purchased at any drug-store and should not cost more than ten cents an ounce.

For making enough blue-print paper for the set of drawings of the lathe, dissolve about one ounce of Citrate of Iron and Ammonia in

four ounces of water, and about three-quarter ounces of Red Prussiate of Potash in four ounces of water. The Prussiate of Potash will dissolve more readily if it is first pounded into a powder. The relative amounts of the chemicals used vary in practice, equal quantities of each being sometimes used. The quantities given above have been found by experience to yield a deep blue color. After the chemicals are dissolved they are mixed together, and the mixture is spread upon the surface of a good, white paper. A soft paste-brush, about four inches wide, will be found serviceable for this purpose. Apply the solution evenly over the entire surface, and tack the sheet up in a dark place to dry. The paper is now sensitive to the action of light, from which it should be carefully guarded. The drying requires about an hour The paper may be kept for some time without deterioration.

In offices where blue-printing is done, special printing frames are provided. These consist of a board upon which two or three thicknesses of flannel or other soft cloth is smoothly fastened, over which is hinged a sheet of heavy glass. The cloth furnishes a smooth, yielding surface upon which to place the paper and tracings, and the heavy glass presses them evenly together while permitting the sunlight to act. The prepared paper is placed upon the cloth, sensitized face up, and the tracing is placed over it. They are held firmly together by the glass, and exposed to the direct action of the sun's rays. The time of exposure varies with the intensity of the sunlight, but from ten to three o'clock an exposure of from five to eight minutes should be sufficient. The printing may be done without the direct action of the sun's rays, as upon a cloudy day, by extending the time of exposure to from one to two hours.

When the paper has been exposed long enough, which is shown by the yellow color changing to a bluish-gray, it is placed on a

bath of clean water, and allowed to soak for a few minutes. It is then rinsed off and hung up to dry.

If a regular printing frame is not attainable, any simple device may be used that will keep the paper and tracing firmly pressed together and not obstruct the action of the sunlight.

If, after a blue-print is made, it is desired to add anything to it, as a measurement or a line, it may be done with an ordinary pen dipped in caustic soda, which bleaches the blue, or Chinese White may be used.

The finished parts of a machine may be shown upon a blue-print by drawing lines with red ink adjacent to such parts.

SHEET XXV.

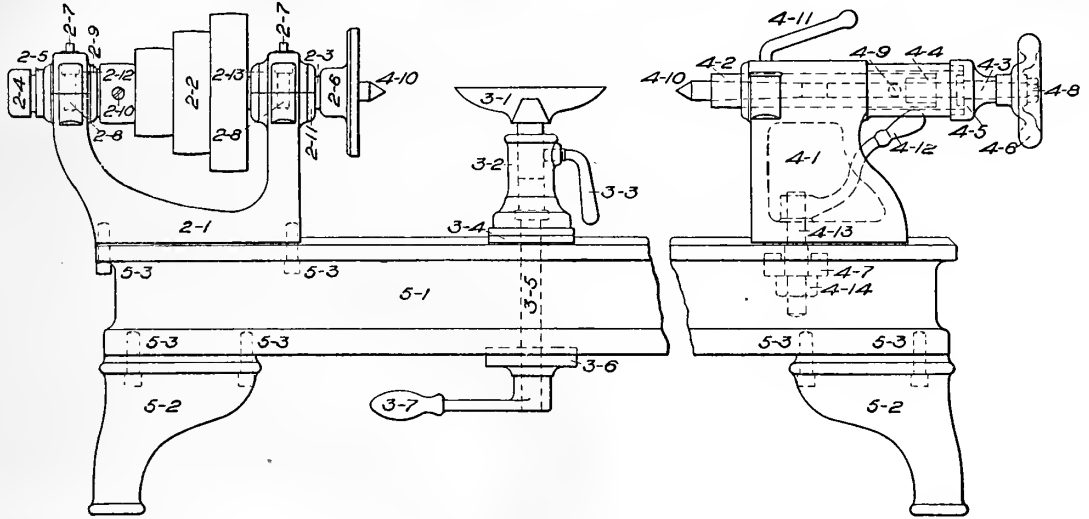
Bench Lathe — Assembly Drawing.

The assembly drawing, although numbered one, is the last to be drawn in the series. It is made directly from the detail sketches. The numbers upon the assembly drawing refer to the numbers of the various parts and show how they are assembled.

For example, the head-stock frame in the assembly drawing is marked "2-1." By looking at the "List of Drawings" given in the lower left-hand corner of the sheet, it will be seen that "2" is the number of the sheet containing the details of the head-stock, and that the number of the frame is "1" on that sheet. Again, the hand-wheel on the tail-stock is numbered "4-6," which means, detail number 6 on sheet number 4.

As a rule, it is better not to shade a drawing. There are places where shade-lining tends to bring out more clearly the meaning of a drawing, but such cases are the exception. This sheet would be quite as serviceable without the shade lines. It adds somewhat of a finish to the drawing, but is here given simply as an example, and to explain the method. The light is supposed to come from the upper left-hand corner of the sheet at an angle of 45°. Therefore, the bottom and right-hand lines are made heavier. The thickness of the shade line should be upon the outside of the line.

Sometimes the principal over-all dimensions are shown on the assembly drawing.



List of Drawings
1- Assembly
2- Head Stock
3- Tool Rest
4- Tail Stock.
5- Bed

Bench Lathe
Assembly.
SCALE - HALF SIZE.
4-8-96. GR. DEL.

L-2-1

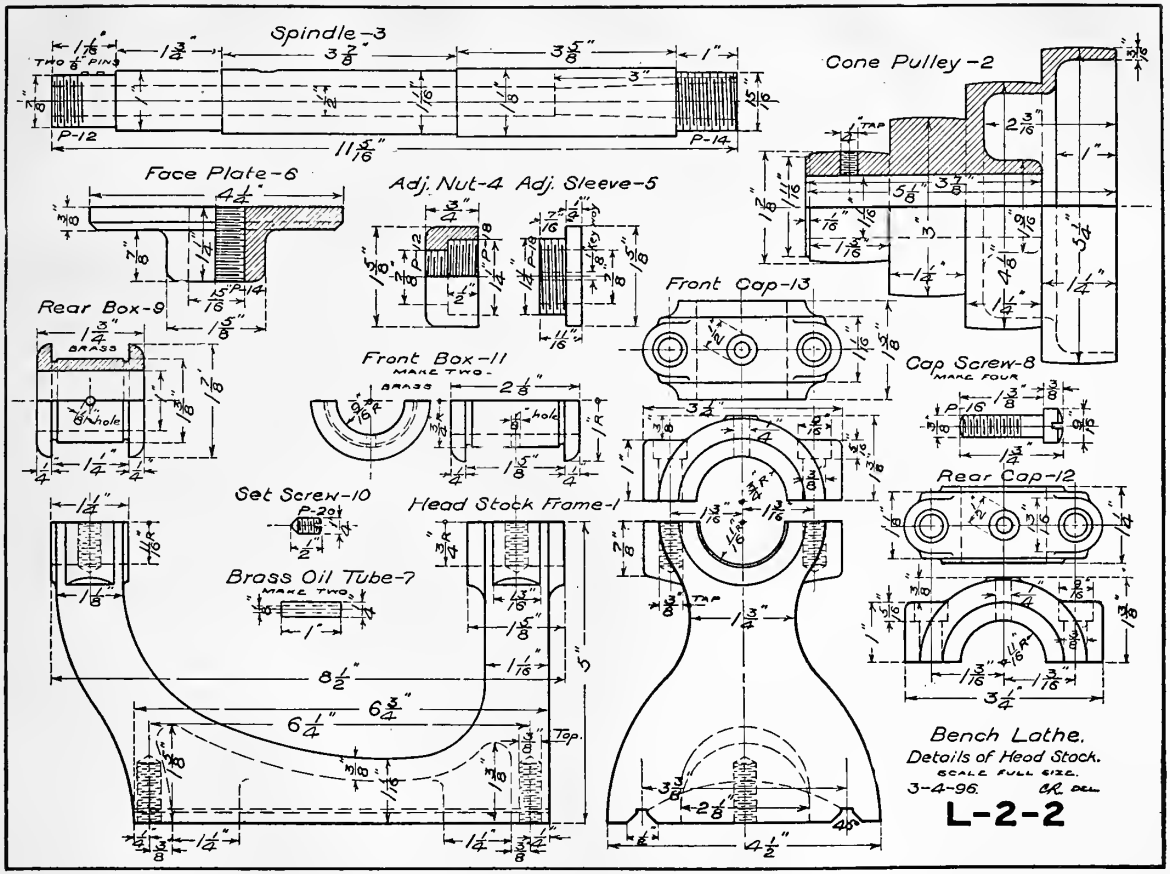
SHEET XXVI.

Bench Lathe — Details of Head-Stock.

The designing of a machine and the making of the original drawings for it is not a subject to concern the student of elementary mechanical drawing. That is the work of the experienced designer and draughtsman. The best practice for the student is to make drawings of some machine already built.

Suppose the bench lathe under consideration to be such a machine. The first thing to do is to take the machine apart and make careful free-hand sketches of each part, fully dimensioning. Section-paper, a paper lightly lined to inches and fractions of an inch, will be found of assistance in making correctly proportioned sketches. From these sketches the mechanical drawing is made in pencil. As every one cannot have a machine to take apart and make sketches of, the student may consider these sheets as sketches and make his drawings directly from them, working to the given dimensions.

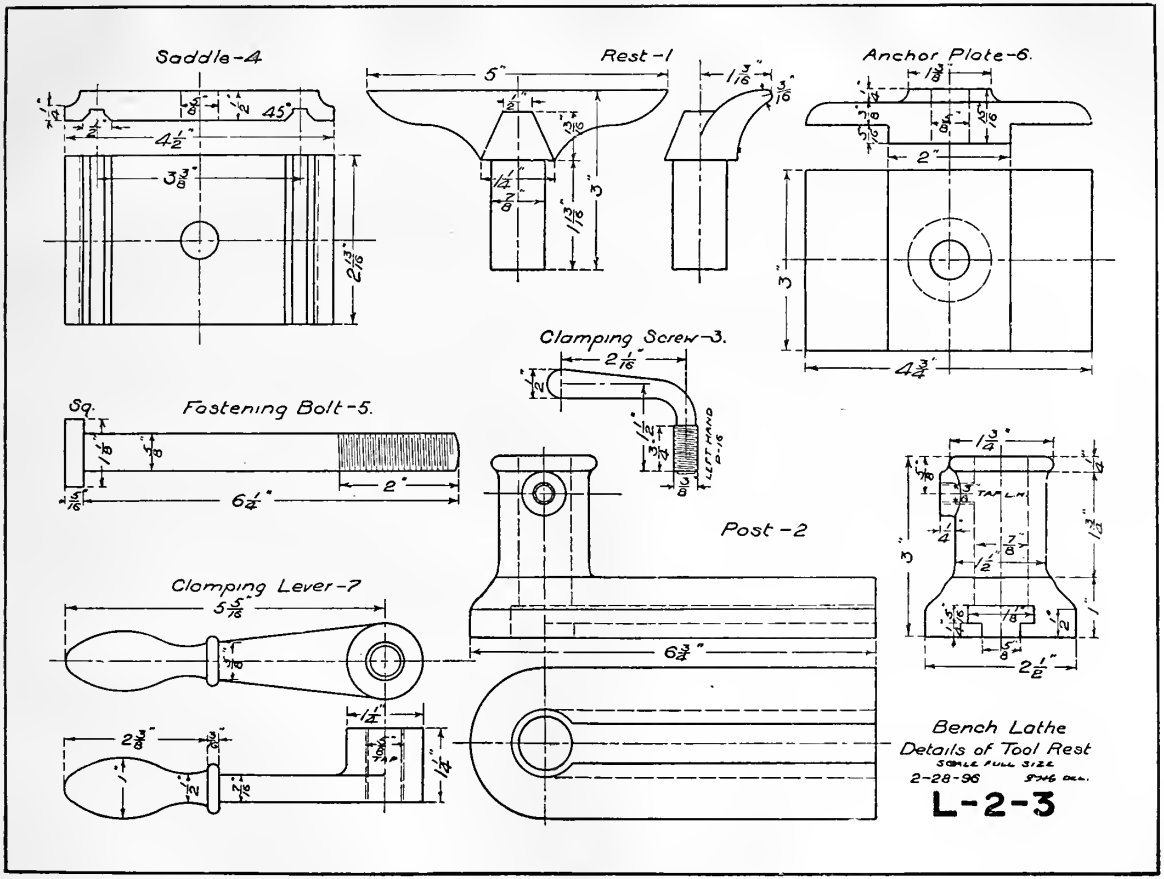
Each detail on this sheet should be carefully studied and the reason for each line and dimension should, with the aid of the preceding explanations, be understood.


Spindle-3
Cone Pulley-2
Face Plate-6
Adj. Nut-4 Adj. Sleeve-5
Front Cap-13
Rear Box-9
Front Box-11
Cap Screw-8
Set Screw-10
Head Stock Frame-1
Rear Cap-12
Brass Oil Tube-7
Bench Lathe.
Details of Head Stock.
SCALE FULL SIZE.
3-4-96.
L-2-2

SHEET XXVII.

Bench Lathe — Details of Tool Rest.

But two views of the post are necessary to give all the dimensions; the bottom view shows a little more clearly the shape of that part of the post. The tap (internal screw-threading) on the post is shown by parallel hidden lines in the side view and by the note, "$\frac{3}{8}$ in. tap." The tap is shown in the front view by two circles. This method is also shown on the clamping lever. Where a definite pitch is not given of screw threads, as in the case of the fastening bolt, it is understood to be standard. The bolt is five-eighths inches in diameter, therefore the pitch of the screw-threading is eleven. (See Table on page 38.)

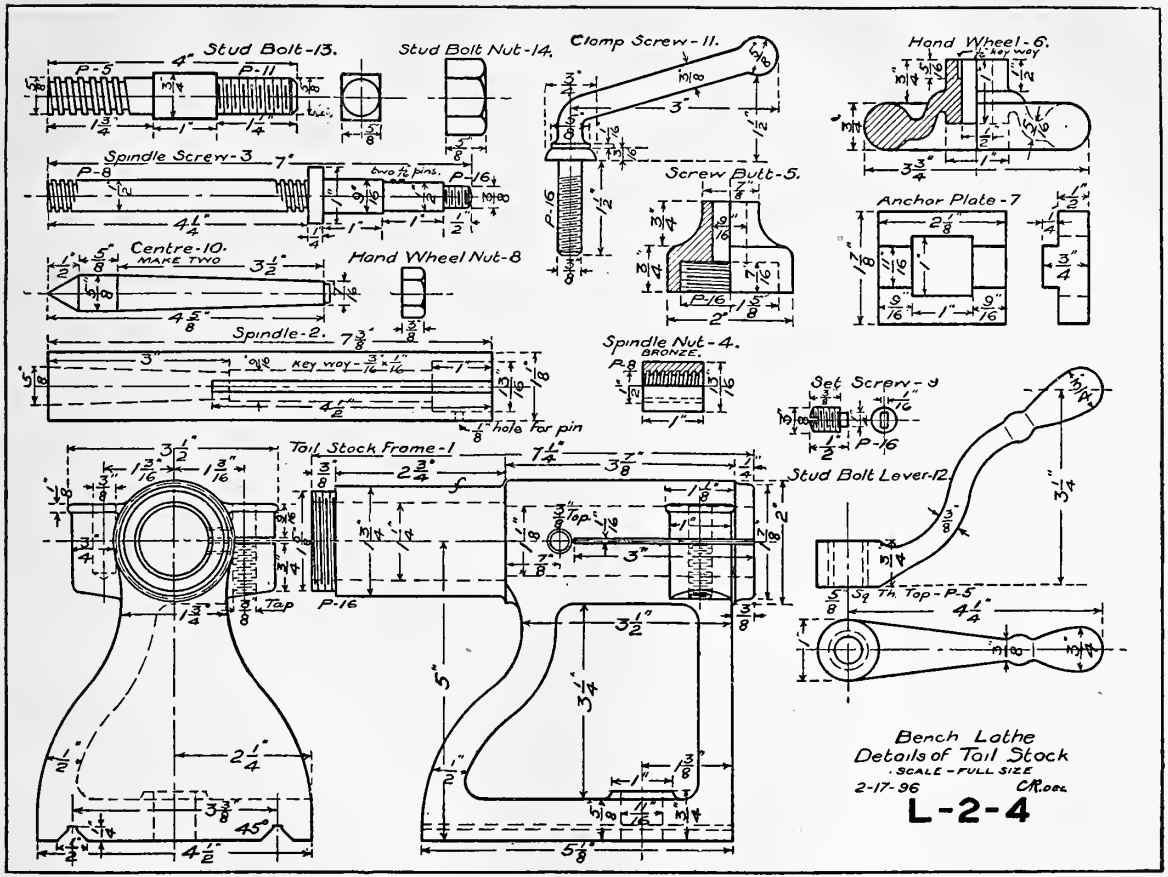

Saddle-4
Rest-1
Anchor Plate-6.
Clamping Screw-3.
Sq.
Fastening Bolt-5.
Post-2
Clamping Lever-7
Bench Lathe
Details of Tool Rest
SCALE FULL SIZE
2-28-98
L-2-3

SHEET XXVIII.

Bench Lathe — Details of Tail Stock.

But one view of the nuts is shown, and in each case the height alone is given. This would indicate that the nuts are standard, and the height of the nut equals the diameter of the bolt. Therefore, the taps of the stud bolt nut and the hand wheel nut are $\frac{5}{8}$-inches and $\frac{3}{8}$-inches respectively. Another method of indicating a tap is given on the tail stock frame, where the thread is shown by conventional hidden lines.

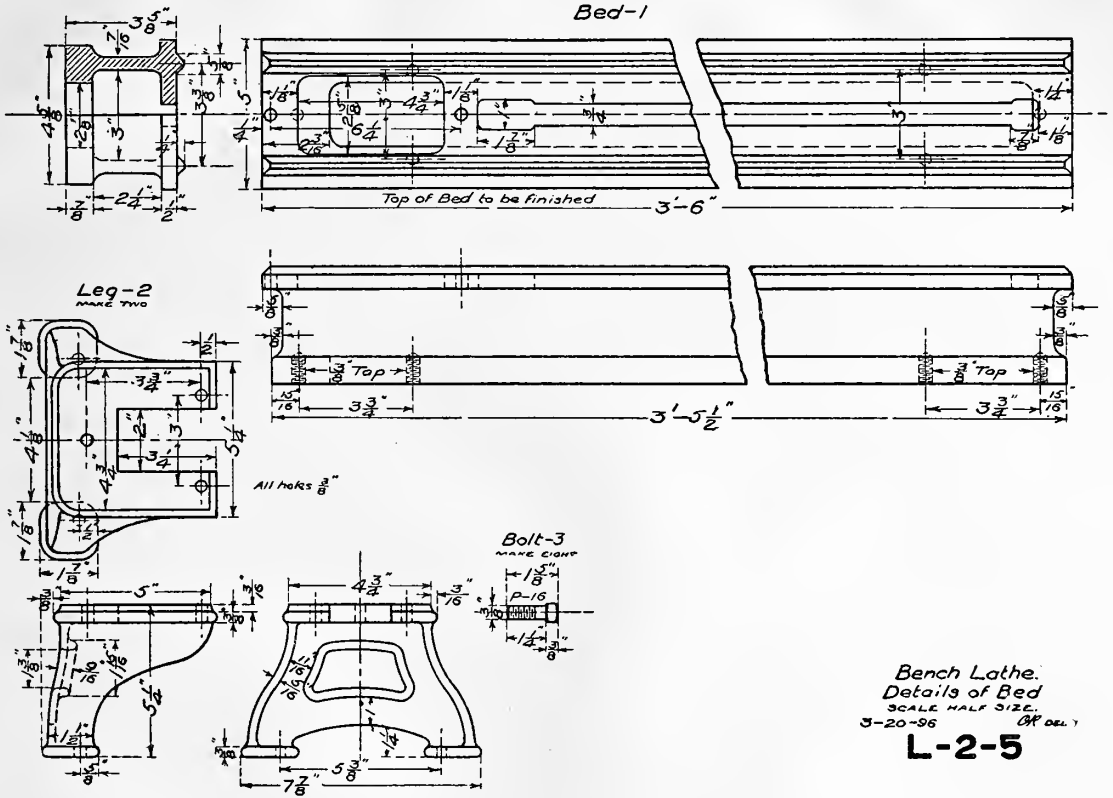
The taper of the centre might have been expressed by giving the amount of rise to each inch.


Stud Bolt-13.
Stud Bolt Nut-14.
Clamp Screw-11.
Hand Wheel-6.
Spindle Screw-3
Screw Bolt-5.
Anchor Plate-7
Centre-10.
MAKE TWO
Hand Wheel Nut-8
Spindle-2.
Spindle Nut-4.
BRONZE.
Set Screw-9
Tail Stock Frame-1
Stud Bolt Lever-12.
Bench Lathe
Details of Tail Stock
SCALE - FULL SIZE
2-17-96
CR.DOC
L-2-4

SHEET XXIX.

Bench Lathe — Details of Bed.

This sheet is drawn to half-scale. As the structure of the bed is the same throughout a considerable length, space may be saved by breaking out a piece and showing only the ends. The dimension over-all is given. The section here shown as an end view is frequently drawn in the broken-out portion as indicating the structure of the object at that part. Sometimes drawings made to different scales are placed upon the same sheet. On this sheet the bed and leg are drawn to half-scale, but the bolt might have been drawn full size, on account of its relative smallness, and a note giving its scale added.



Bench Lathe.
Details of Bed
SCALE HALF SIZE.
3-20-96 CR DEL.

L-2-5

SHEET XXX.

Isometric Drawing.

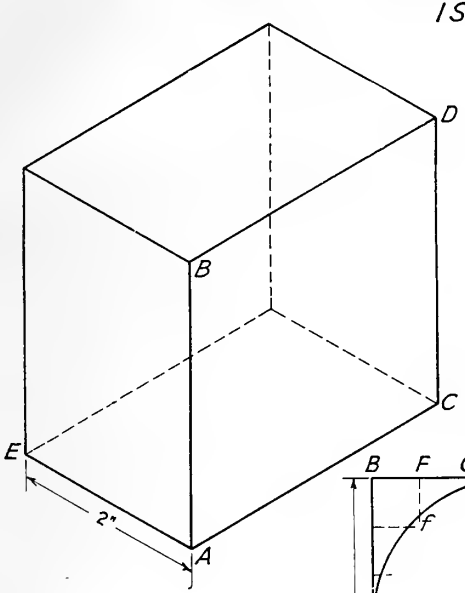
Isometric drawings are relatively easy to make and understand, and in a single view give information that in an ordinary mechanical drawing would require two or more views. They have the disadvantage of appearing distorted and also of limiting measurements to three directions.

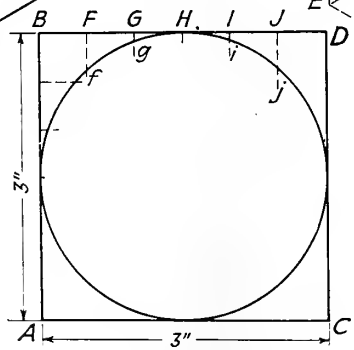
In making an isometric drawing all vertical lines, or lines representing height, as line A B, are drawn as vertical lines; all lines representing widths, as line A C, are drawn at 30° to the right; and all lines representing depth, as line A E, are drawn 30° to the left. On these three lines, and lines parallel to them, measurements may be made, but all other lines will vary from their true length. E.g. A B and A C are 3 inches long in both the front view and in the isometric view, and A E is 2 inches. But take any line outside of the isometric lines, as the distance A D; on the front view the true measurement of this distance is found to be about $4\frac{1}{4}$ inches, whereas in the isometric view it is about $5\frac{1}{8}$ inches.

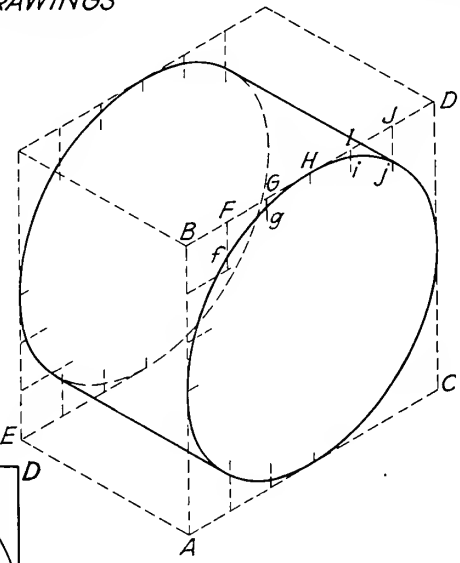
Draw the 3-inch square shown at the bottom of the sheet and then draw the same square in isometric projection. First draw the vertical line A B and then the lines A C and B D at 30° to the horizontal. Draw A E at 30° and fill in the remaining lines.

Inscribe a circle in the square. To make an isometric drawing of this circle first make the isometric view of the square as shown in the right-hand upper corner. Divide B D into a number of equal parts, as at F, G, H, I and J. From these points drop vertical lines and on these lines take the measurements F f, G g, etc. Carry out the same method with the other three sides of square. The result will be a series of points f, g, h, i, j, etc., through which a smooth curve should be drawn. This curve will prove to be an ellipse, which is the isometric drawing of the circle. By drawing the rear ellipse and the two connecting tangent lines an isometric drawing of a cylinder is obtained. Any curve may be drawn isometrically by the method of offsets used in making this isometric drawing of a circle.

ISOMETRIC DRAWINGS





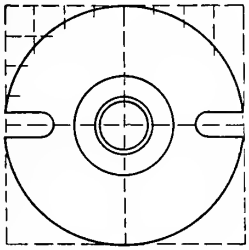


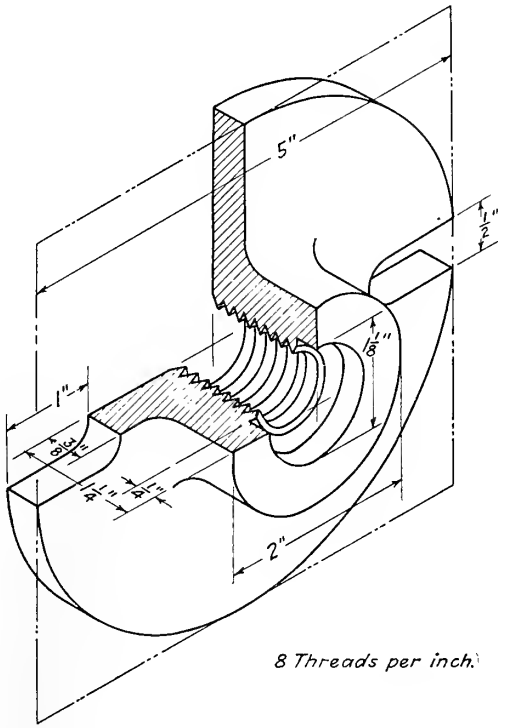
SHEET XXXI.

Isometric Drawing of a Face Plate.

As a practical example of the application of isometric drawing a face plate is shown in Sheet XXXI. Having made the isometric drawing of the circle in Sheet XXX the student will readily comprehend the method of making this or a similar drawing.

FACE PLATE





8 Threads per inch.

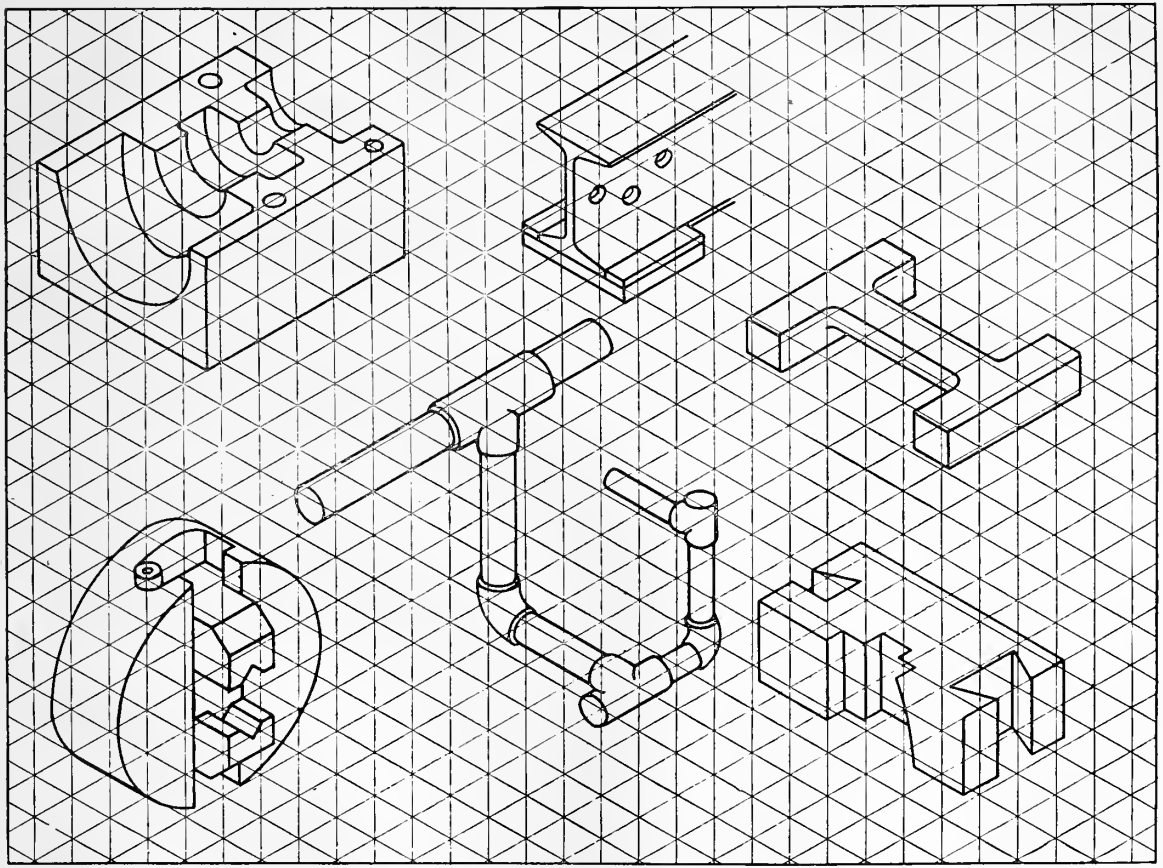
SHEET XXXII.

Isometric Sketching.

The Norman W. Henley Publishing Company, at 2 West 45th Street, New York, has placed upon the market an isometric sketching paper * that affords a convenient and ready means of making isometric drawings. The isometric lines are lightly printed upon the paper and with these as a background isometric drawings may be readily made. Sheet XXXII shows the method of using the prepared paper.

* This isometric paper is supplied in pads as follows:

Pads (40 sheets) 6 x 9	40 cents
Pads (40 sheets) 9 x 12	75 cents
Pads (40 sheets) 12 x 18	$1.50



PARALLEL COURSE.

PARALLEL COURSE EXERCISES

THE following exercises constitute an independent series, parallel to the regular course, and may be pursued in preference to the regular course by those who desire to avoid any tendency towards copying. Each sheet differs but slightly from the corresponding sheet of the regular course, and may readily be drawn from the directions accompanying the regular sheet.

EXERCISE I.

Square Prisms. Draw the top and front views of a square prism, the base of which is 2 inches square and the height 3 inches. Show three positions as in **Sheet I.**

EXERCISE II.

Triangular and Hexagonal Pyramids. A pyramid differs from a prism in that its sides meet in a point. Draw the top and front views of a triangular pyramid 4 inches in height and having each side of the base 2 inches. Also draw the top, front, and left-hand views of a hexagonal pyramid 4 inches in height, having each side of the base $1\frac{1}{8}$ inches.

EXERCISE III.

Projection of a Square Prism. Draw the front, top and two side views of a square prism, having an altitude of 4 inches, base 2 inches square, and tilted 30° to the right.

EXERCISE IV.

Projection of a Double Cross. Add to the cross shown in **Sheet IV** another arm, at right angles to the one given, and of similar dimensions. The top view will then present a cross, the arms of which are each one inch square. Draw the various projections shown in **Sheet IV.**

EXERCISE V.

Sectioned Views. Draw the top and front views, and half-section of a square prism, 4 inches high, with $2\frac{1}{2}$-inch base, and having a bore of $1\frac{1}{2}$ inches in diameter.

Also draw the top and front views of a similar prism having a flange at the top and bottom $\frac{1}{2}$ inch high and overhanging $\frac{1}{4}$ inch. Show one-half of the front view in section.

EXERCISES VI AND VII.

Joints. Make working drawings of two simple joints, as of a Lap Joint and a Sash Joint.

EXERCISE VIII.

Development of a Rectangular Block. Draw the development of the surface of a rectangular block, 3 inches long, 2 inches deep, and $2\frac{1}{2}$ inches high.

EXERCISE IX.

Development of a Rectangular Pyramid. Draw the top and front views, and the development of the entire surface of a pyramid having a rectangular base $2\frac{1}{2} \times 2$ inches, and an altitude of 4 inches.

EXERCISE X.

Development of a Truncated Square Pyramid. At half the altitude of the square pyramid of **Sheet IX** make a cut at 45° to the base and develop the entire surface of the lower part, including the cut surface. It will be necessary to show the cut in the top view, and this may be obtained by projecting the intersections of the cut and the sides of the pyramid to these sides as shown in the top view, and by joining the points thus found. The entire drawing of **Sheet IX** should first be made, as the cut is then more readily determined.

EXERCISE XI.

Development of an Elliptical Cylinder. Draw the top and front views, and the development of a cylinder having an altitude of 4 inches, and an elliptical base, the major (longer) axis of the ellipse being $2\frac{1}{4}$ inches and the minor (shorter) axis $1\frac{3}{4}$ inches. Cut the cylinder by an inclined plane and develop the cut. The ellipse is stepped off into a number of equal parts as in the case of the circle in **Sheet XI.**

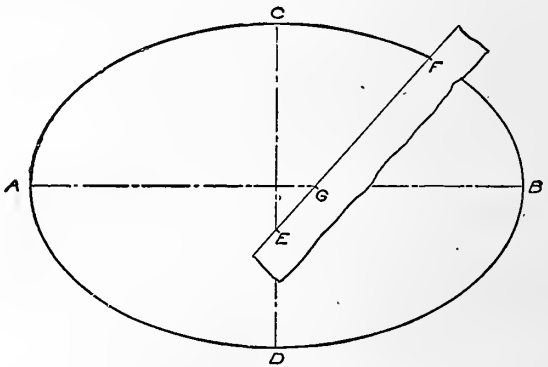


FIG 4.

A simple method of drawing a true ellipse, when the major and minor axes are known, is shown in the diagram Fig. 4. Let A B be the major axis and C D the minor axis. On a slip of paper lay off E F equal to

one-half A B, and G F equal to one-half C D. Then keeping the point E always on the line C D and the point G always on the line A B, the point F will describe the required ellipse. Find a number of positions of the point F and through these points draw a smooth curve.

EXERCISE XII.

Development of an Elliptical Cone. Draw the top and front views, and the development of a cone having an altitude of 4 inches, and an elliptical base, the major axis of the ellipse being $2\frac{1}{4}$ inches and the minor axis $1\frac{3}{4}$ inches. Cut the cone by an inclined plane and develop the cut.

EXERCISE XIII.

Development of a Five-Piece Elbow. Draw the front view and development of a five-piece elbow of the same general dimensions as given for the four-piece elbow.

EXERCISE XIV.

Screw Threads. The regular sheet on Screw Threads contains, in a compact form, much with which the student of the subject should be familiar. Any departure from the general make-up of the sheet should, therefore, not be attempted. A slight variation of the dimension given is the only change that should be made. This will be sufficient to give a somewhat different curvature to the lines.

EXERCISE XV.

Springs. Sheet XV may be varied by closing the springs until the spaces are but three-quarters of the distances given, while the other dimensions remain the same.

EXERCISE XVI.

Bolts and Nuts. Substitute for the two bolts and nuts of **Sheet XVI** similar ones of $1\frac{3}{4}$ inches diameter of bolt, and 7 inches in length. Lay lengthwise of the sheet and draw without the top views of the nuts, by the method given in the latter part of the explanations accompanying **Sheet XVI.** Give all dimensions shown by letters in **Sheet XVI.**

EXERCISES XVII TO XXIV.

Simple Working Drawings. Make working drawings of small articles that are not complex in their character. The following list may be suggestive of suitable material:

Various kinds of pulleys, clamps, wrenches, valves, simple vises, faucets, anvils; shafting details — as couplings, pillow-blocks, and hangers; engine details — as ends, cranks, eccentrics, cross-heads and guides, etc.

EXERCISES XXV TO XXIX.

Working Drawings. Make a complete set of working drawings of some small machine, like a drill-press or bench-lathe, or of a small engine.

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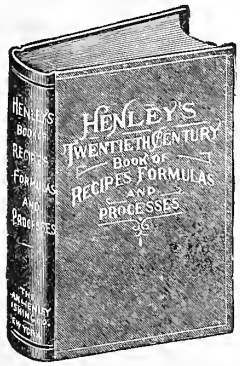

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